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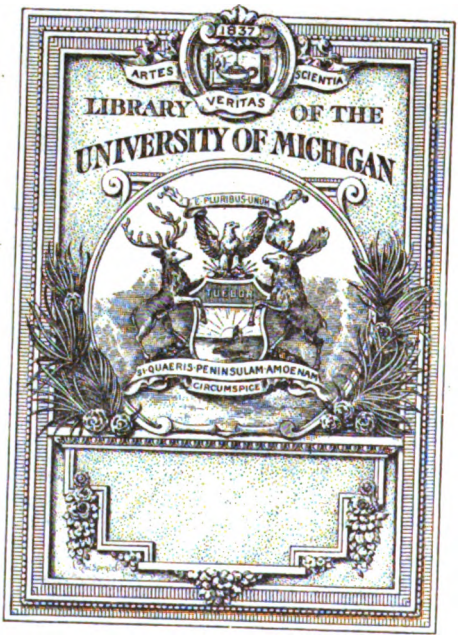

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THE ROYAL ASTRONOMICAL SOCIETY
TO
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MONTHLY NOTICES

OF THE

40882

ROYAL ASTRONOMICAL SOCIETY,

CONTAINING

PAPERS,

ABSTRACTS OF PAPERS,

AND

REPORTS OF THE PROCEEDINGS

OF

THE SOCIETY,

FROM NOVEMBER 1876 *TO NOVEMBER* 1877.

VOL. XXXVII.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. NOVEMBER 10, 1876. No. 1.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

George Spedding Almond, Esq., Daisy Hill, Dewsbury;
Josiah Owen Corrie, Esq., B.A., Red Cot, Putney Park Lane;
Capt. Joseph Leeman, Aberdeen; and
Herbert Sadler, Esq., Honiton Rectory, Devonshire;

were balloted for and duly elected Fellows of the Society.

Note on a Method of obtaining Equatoreal Motion by means of a simple addition to an Altazimuth Stand. By Lord Lindsay.

If we take a telescope mounted with vertical and horizontal motion, these may be converted into equatoreal motion by the addition of a bar of metal or wood.

At any convenient distance below the altitude axis of the instrument let a bar be fixed at right angles to the pillar or azimuth axis. In the bar there should be a V-shaped slot, through which a string or wire may slide, and be clamped by a screw pressing it into the angle of the V.

Let the bar project in the plane of the meridian to such a distance that the angle contained between the bar and a line drawn from the V-shaped slot to the centre of motion of the altitude axis is equal to the latitude of the place of observation.

In other words, let the distance of the angle of the V-shaped slot from the central line of the pillar of the instrument be equal to the distance from the upper side of the bar to the centre of motion of the altitude axis multiplied by the cotangent of the latitude of the place of observation.

The object-glass end of the telescope should now be connected with the V-shaped slot by means of a fine wire or string, and a

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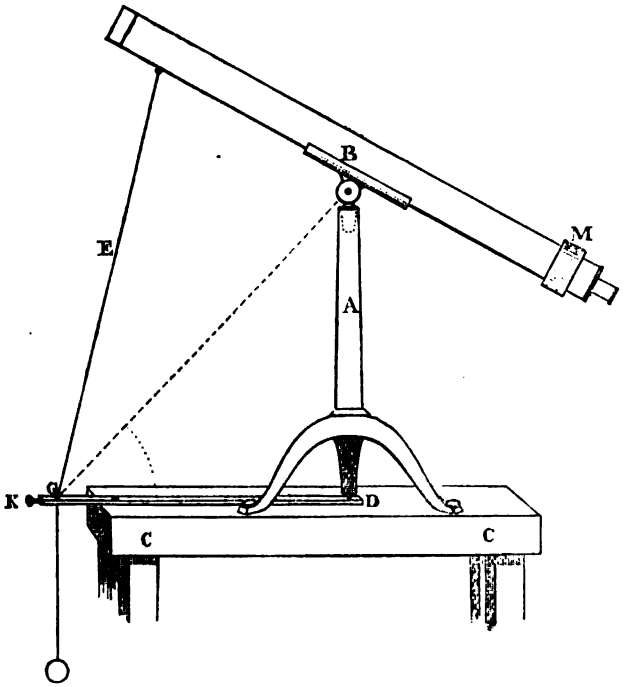
weight may be attached at the other end of the telescope, in order to keep the wire always stretched. On moving the telescope while the wire remains clamped it will be found, as is



A Stand.
C Table.
E Controlling line.
Angle DGB = Latitude of place.
B Centre of Alt. motion.
D K Rod.
K Pinching screw to clamp-line E.
M Weight to keep E tight.

evident, that the telescope can only move in a parallel of declination. If it is wished to follow another star, the wire must be unclamped and the telescope re-set. The equatoreal motion thus produced will be found to be quite sufficiently accurate for all ordinary purposes.

The method is so simple that I think it must have occurred to other persons; but as I have not seen any account of it in print, I have thought that it might be worth while to mention it to the Society.

Note.—Since writing this paper, my attention has been drawn to the fact that Sir George Airy, in the 15th vol. of the *Monthly Notices*, has described a mounting for a large telescope on this principle; with the difference that he placed the point of attachment of the cord to the north instead of to the south of the telescope.

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Description of an Improved Altazimuth Stand for Reflecting Telescopes, with a new Form of Binocular Eyepiece. By W. H. Thornthwaite.

Having been requested by Mr. H. Alers Hankey, of Queen Ann's Mansions, to provide some form of Binocular eyepiece especially applicable to telescopes of large aperture, such as the 12½-inch Equatoreal, with silvered glass mirror, which my firm were constructing for him, several experimental eyepieces of various forms were tried, and also a considerable amount of time and thought devoted to the subject of Binocular vision in connection with the telescope. I hope a short account of these experiments and their ultimate results may prove of interest to the Fellows.

There are two important advantages to be obtained by Binocular vision, the first being, as the name implies, the employment of both eyes, instead of confining observation to either the right or left eye; the second advantage consists in the apparent stereoscopic effect produced when both eyes are employed. In respect to the first-mentioned advantage, it will be admitted that the constant use of one eye must, after a time, be injurious both to that employed and also to its fellow. To take an extreme case, it is found that a single spectacle lens considerably injures the sight; the eye which is *not* assisted by the glass becoming after a time of a different focus to the other. But when both eyes are brought into action no such unpleasant results accrue; and as the observer discontinues his telescopic work, he finds his eyes are not nearly so fatigued by long-continued gazing as they would have been if only one eye had been used.

Secondly, it is impossible that any *real* stereoscopic effect can be noticed in viewing objects so distant, but it may be asserted that a considerable *apparent* effect is produced by Binocular vision. The rotundity of the Sun and Moon, and the mountainous surface of the latter, stand out in bold relief; *Jupiter* and *Saturn* appear *surrounded* by their Satellites, and not, as in an ordinary eyepiece, as a flat picture.

Having made these few general remarks on Binocular vision, I beg to append my own experience, and a short description of the eyepiece now exhibited.

The first eyepiece tried was an ordinary Binocular microscope, with an extra large "Wenham" prism. Except on the Moon, this form was found to be very trying to the eyes, on account of the strain put on them in order to make the two dull fields of the eyepieces coincide: using this form for a few minutes occasioned considerable giddiness. No such visual strain is experienced with a Binocular microscope in its ordinary employment, as the fields are much brighter, and therefore more easily made to coincide. Several other plans of dividing the cone of rays were tried without much success, the great difficulty being that the division must occur so close to the eyepieces, that their

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fields, with even moderately low powers, were only partially illuminated.

The Binocular now exhibited has neither of the preceding defects, the fields of low-power eyepieces being entirely illuminated, and it can be used for any length of time without tiring the eyes. Its principal disadvantage is the loss of light occasioned by several reflexions, but as with even moderately large telescopes, the light of the Moon and of some of the planets is excessive, especially to sensitive eyes, this defect must sometimes be an advantage. I may here remark, that I am now constructing a Binocular on a somewhat similar plan, but substituting prisms for silvered flats, and in which therefore the loss of light will be very small.

The principle of this instrument is very simple, and is as follows:—The rays of light from an object-glass or speculum fall on a silvered glass, placed at an angle of 45°, from this they are reflected at an angle of 90° to another silvered glass, parallel to the first, and thence to one eyepiece. But the first reflecting surface is an exceedingly thin coating of silver on a glass with parallel sides; a portion of the light is therefore transmitted through the transparent silver film, and then by two more silvered glasses it is reflected to the other eyepiece. The object of silver film is to avoid the secondary image which would be reflected from the inner side of the glass. The eyepieces are therefore side by side, and have their optical axes parallel; direct vision with each eye is thus obtained. The eyepieces have each an independent focussing slide, and they can be separated to accommodate different observers whose eyes may be various distances apart; this separation is affected by the milled head, the screw on one side of which is right-handed, and on the other left-handed; on revolving the milled head, therefore, the eyepieces are separated or brought nearer together. If solar or first surface prisms were used for the several reflexions, the instrument would form a Binocular for observations of the Sun.

The 8½-inch Altazimuth on which the eyepiece is now shown, in order that the Fellows may roughly test its binocular performance, has been constructed with several important improvements. I will merely call attention to them in order that the Fellows may practically test their utility.

The open tube now adopted is so made that it shows that *any* closed tube may be similarly altered. The altitude clamp is of a novel kind, and is brought for convenience close to the eyepiece. Lastly, the screw motion in azimuth is continuous throughout the entire circle, or may be at pleasure thrown out of gear.

1876, *Nov.* 9.

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Measurement of the Direct Effect of Sun-spots on Terrestrial Climates.

By Prof. S. P. Langley.

(*Communicated by E. Dunkin, F.R.S.*)

Since the question of the influence of Solar changes on Terrestrial climates was opened by the elder Herschel, a great number of Meteorological observations have been tabulated and discussed without the apparent attainment of any conclusive result, nor does there seem to be immediate hope of any solution from the study of such Terrestrial effects, while the evidence from these bears so different a meaning according to the interpretation of the compiler.

Though complete knowledge on this point seems still far beyond our reach, yet, if we consent to limit our enquiry to the *direct* effect of Sun-spots on the heat the Earth receives, there is, it seems to me, an untried means, which yields a sufficiently exact solution of the problem. It appears possible at least, to show (within certain definite limits) by how many degrees or parts of a degree Centigrade the Earth's mean annual temperature necessarily varies between a year of maximum and a year of minimum Spot-areas so far as the immediate effect of these on the solar thermal radiation is concerned.

To do this it is necessary,—

(1) To procure from experiment trustworthy measurements of the relative amounts of photospheric, penumbral, and umbral radiation.

(2) To determine the relative photospheric, penumbral, and umbral surfaces, in a maximum and in a minimum year, and (having suitably combined these data) to

(3) Show within what specific limits we can assert that the Terrestrial temperature will be necessarily changed.

The first condition, is so far as I know, heretofore unsupplied, owing to the experimental difficulties which have only lately been overcome. The results of recent measurements at the Allegheny Observatory now published for the first time will furnish these data.

For the second condition, I shall avail myself of the published results of Schwabe, Carrington, De La Rue, and others.

For the third, a method will be employed which, if in some measure novel, is apparently a legitimate deduction from facts in themselves not open to question.

1. *Direct Thermal Measurements of Solar Radiation.*

Since the original observations of Henry, in 1845,* established the important fact that the thermal radiation of a spot is in general

* *London, Edinburgh, and Dublin Philosophical Magazine*, 3rd Series, 1846, p. 230; Poggendorf's *Annalen*, 1846, vol. 68, p. 102.

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less than that of the photosphere, nothing appears to have been added to show by how much it differs. If quantitative results have, in spite of their obvious value, never been obtained, it is doubtless owing to the experimental difficulties we meet in passing from the point at which we can say that the spot-radiation is less, to that at which we can say with confidence *how much* it is less. To but partially indicate the nature of these difficulties, we may observe that the umbra of a sun-spot occupies so small an area, that the quivering of the telescopic image, due to atmospheric tremor, commonly causes its libration through a range on either side of its mean position exceeding its own semi-diameter. Whatever the size and stability of the telescope, or whatever the enlargement of the image, or the minuteness of the thermopile we seek to expose only to umbral heat, penumbral radiations will then be registered to some extent, or if it be penumbral radiation we would observe, umbral and photospheric heat will alternately enter with it. This is no serious drawback, if we seek to show only, that the spot as a whole is cooler or hotter without enquiring in what degree; but obviously it is fatal to accuracy, when we would determine by how much the radiation is diminished by each part. We must either take the telescope beyond the limits of our lower atmosphere then, or observe only in those rare and brief periods when the image is still. These periods in our northern climates are always associated during the day with the presence of moisture and haze in the atmosphere. It is almost superfluous to remark that these conditions, which secure a tranquil image, are precisely those most unfavourable to the transmission of radiant heat, and the excessively diffuse and enfeebled rays which form the enlarged image, are, in spite of every precaution, apt to be confused with radiations which reach the pile from extraneous sources.

Trials were made in 1873 and 1874 of a great many plans, for so shielding the pile that it might be absolutely protected against every source of disturbance except the minute pencil of umbral or penumbral rays, with incomplete success, till in the close of the latter year an apparatus was devised by the writer with which, though the time for large spots was passed, satisfactory measures were at last obtained.

The apparatus cannot be fully explained without illustration; the essential conditions of success, however, are that to an eye placed in the position of its working face the part of the spot to be studied and the blackened walls of a chamber surrounded by water at a constant temperature are alone visible, and that provision is yet made for the observer's ability to verify at any moment the position of the image projected on this hidden face, which is maintained at all times in the optical axis. The pile specially constructed by the late Mr. Becker is composed of very minute elements and used in connection with a reflecting galvanometer. The use of a large Equatoreal with accurate clock-work is of course presupposed. That employed was a refractor (and

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it will hence be understood that our measurements are confined to luminous heat rays), having an aperture of 13 inches. The projected image was formed on a scale of from four to eight feet to the solar diameter.

The pile was ordinarily first placed in the image of the photosphere, between the spot and the centre of the disk, and the galvanometric deflexion noted; next an exposure of equal length in the umbra was made, and then the observation once more repeated with the pile in the adjacent photosphere between the spot and the limb. The mean of the photospheric readings, after the instrumental reductions are applied, is used as a divisor for the (reduced) umbral reading. The quotient expresses the value of the umbral radiations, in parts of those of the adjacent photosphere. The decrement of heat, as we approach the limb, is, though not exactly, yet so very nearly, in the same ratio for photosphere and spots, that no correction is needed on this account for the present observations. Thirty-six measurements on Umbræ, and thirty-two on Penumbræ, were obtained in the autumn of 1874 and the spring of 1875, as follow:—

Umbral Heat-radiation (Photospheric Radiation = 1·00).	Penumbral Heat-radiation (Photospheric Radiation = 1·00).
0·55	0·86
0·43	0·74
0·49	0·92
0·49	0·98
0·55	0·80
0·61	0·68
0·61	0·82
0·53	0·80
0·55	0·84
0·63	0·73
0·57	
0·50	0·74
0·49	0·83
0·53	0·84
0·54	
0·49	0·75
0·53	0·73
0·57	0·84
0·57	0·79
0·61	0·69
0·52	0·71
0·49	0·81
0·51	0·77

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Umbral Heat-radiation (Photospheric Radiation = 1·00).	Penumbral Heat-radiation (Photospheric Radiation = 1·00).
0·54	
0·59	0·89
0·54	0·83
0·52	0·62
0·47	0·82
0·60	0·74
0·53	0·74
0·47	0·82
0·52	0·74
0·52	0·96
0·54	0·89
0·54	0·89
0·58	
Mean 0·54 ± 0·05	Mean 0·80 ± 0·01

The result is, that taking the mean thermal photospheric radiation in the spot's vicinity as unity, the mean Umbral radiation is fifty-four one-hundredths (with a probable error of five one-thousandths), the mean Penumbral radiation eighty one-hundredths (with a probable error of one one-hundredth). These errors include all discrepancies due to the greater or less approach to the limb in the spots measured, or due to absolute differences in their radiation, as well as the errors of observation.

(2.) *Comparison of Umbral and Penumbral Areas in a year of maximum with those in a year of minimum.*

To determine the spotted area of the disk in years of maximum and of minimum, I have taken from a paper by Messrs. De La Rue, Stewart, and Loewy, in the *Philosophical Transactions* ('Researches in Solar Physics,' No. 2, page 115), the following dates:—

Maximum	Dec. 31, 1836	Minimum	Sept. 21, 1843
„	Nov. 14, 1847	„	April 21, 1856
„	Sept. 7, 1859	„	Feb. 14, 1867

In the same Memoir, under Table 8, is given for every 14th and 28th day of the month from 1832 to 1868, the total spot-area in millionths of the Sun's visible hemisphere, deduced from the observations of Schwabe, Carrington, and the authors; and, by addition of the fortnightly means, we obtain the following annual ones for three years of maximum and three of minimum:—

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For 6 months preceding and 6 months following	Dec. 28, 1831	Spot area =		·034670
„ „	Sept. 21, 1843	„ „	·002555	
„ „	Nov. 14, 1847	„ „		·031055
„ „	April 28, 1856	„ „	·000850	
„ „	Sept. 14, 1859	„ „		·034530
„ „	Feb. 14, 1867	„ „	·002115	
			·005520	·100255

Whence we find the mean spot-area at any time in a year of maximum = ·001392, in a year of minimum = ·000077; figures which are deduced from a large number of spots distributed with approximate uniformity in longitude, and which hence represent not alone the total spot-area in part of the visible hemisphere, but the total apparent area in parts of the visible disk.

From an enumeration of every Umbral and Penumbral measurement recorded by the authors, from February 7, 1862, to December 31, 1863, we obtain—

$$\frac{\text{Mean Umbral Area}}{\text{Mean Spot Area}} = \frac{21371}{79747} = \cdot 27;$$

$$\frac{\text{Mean Penumbral Area}}{\text{Mean Spot Area}} = \frac{58377}{79747} = \cdot 73.$$

These figures obtained from observations made at a period midway between a maximum and a minimum doubtless represent with approximate truth the relative Umbral and Penumbral areas at other periods. Hence, we conclude that the

Mean Apparent	Umbral	Area in a year of	Maximum	= ·001392 × ·27 = ·000376
„	Penumbral	„	„	= ·001392 × ·73 = ·001016
„	Umbral	„	Minimum	= ·000077 × ·27 = ·000021
„	Penumbral	„	„	= ·000077 × ·73 = ·000056

We have now to multiply each area by its measured rate of thermal radiation already found. Thus, we obtain

·000376 × ·54 = ·000203	·000021 × ·54 = ·000011
·001016 × ·80 = ·000813	·000056 × ·80 = ·000044
·001016	·000055

and since it thus appears that the average spot-radiation earthwards in a year of maximum is ·001016, and in a year of minimum ·000055 of that of the apparent disk, it follows that the total effect of the spots in diminishing the solar radiation by the diminished heat from the increased area they periodically occupy, will not exceed the difference of these numbers or

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·000961. The figure in the sixth decimal place having no real significance, and that in the fifth being doubtful, we may say that the greatest admissible direct effect of the spots is to diminish the Sun's thermal radiation by a quantity somewhat less than $\frac{1}{10}$ and somewhat greater than $\frac{1}{11}$ of one per cent.

(3) *Limits within which Terrestrial Temperature will be affected by such Changes.*

An exact computation of the effect of the Solar radiations on Terrestrial Temperatures requires a knowledge of the heat the Earth receives from other than solar sources. A number of eminent Physicists have attempted to determine this, but with results which are so discrepant that we can feel, as it seems to me, little confidence in their use. The method here adopted, will not assume any knowledge as to the "temperature of space," or any of the other as yet indeterminate factors, indispensable to a complete solution of the problem: we shall therefore not attain an exact result; but we shall be able to feel confident that we can say with assurance within what limits the truth must lie.

There seems to be no question that a temperature as low as −56°C. has been observed in the open air of the Arctic regions, and it is plain that were the Sun's heat altogether withdrawn, the mean Terrestrial temperature would fall at least as low. Independently of stellar radiation, the Earth receives at the upper limit of its atmosphere a certain amount of heat from non-luminous interplanetary matter, which has absorbed and is radiating obscure heat originally derived from the Sun. Computations of the amount of this obscure radiation indicate that it is more considerable than might be supposed; but as little value attaches (it seems to the writer) to such estimates, they are referred to, only to enforce the statement that were the Sun's heat wholly cut off, whatever the mean temperature the Earth might attain it would certainly be below −56°C., and as its actual mean actual temperature is estimated at from +14° to +16° Centigrade, it is clear that to the entire solar thermal radiations not less than 70° C. of our actual temperature is due.

The least change in solar heat due to the cause we discuss being, as has been shown, $\frac{1}{10}$ of one per cent. of the whole radiation, whose thermometric effect registered here is a change of at least 70°C. we find $\frac{0°·7}{11}$=0°·063C. as the *least* change in Terrestrial temperature which we can attribute to the direct effect of the spots.

Again, since the Earth can in no circumstances part with more heat than it possesses, we may, taking the absolute zero as at

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$-274°$ C. say that $16°+274°=290°$ C. represents the greatest effect we can assign to the Sun, and that since the greatest change in solar radiation due to the spots is shown to be less than $\frac{1}{10}$ of one per cent. $\frac{2°\cdot9}{10} = 0°\cdot29$ C., is the *greatest* change in Terrestrial temperature which can be due to this cause.

In all that has preceded it has depended on certain data drawn from observations made by means which exclude the measurement of the thermal effect due to rays in the ultra-red and ultra-violet parts of the spectrum, but were these obtainable, there seems no probability that these conclusions would be materially affected.

To prevent misapprehension, let it be repeated that nothing is here given as being to the writer decisive of the question—whether Terrestrial temperature may not be quite otherwise affected by some varying Solar action of which spots are merely accompaniments—and then, with this understanding, we may reach the following conclusion:—

Sun-spots do exercise a direct and real influence on Terrestrial climates by decreasing the mean temperature of this planet at their maximum. This decrease is, however, so minute, that it is doubtful whether it has been directly observed or discriminated from other charges. Its whole effect is represented by a change in the mean temperature of our globe in eleven years, not exceeding three-tenths, and not less than one-twentieth, of one degree of the Centigrade thermometer.

Allegheny Observatory, Allegheny, Pa.,
1876, June 16.

Observations of the Solar Eclipse of 1876, September 17.

By John Tebbutt, Esq.

The atmosphere was calm and clear. At the time of first contact the Sun was low, but the undulation along the limb was not so great as I expected; this phase was, therefore, pretty well observed. The observation of the last contact was very satisfactory. The following are the Observatory local mean times of observation:—

	d	h	m	s
First contact	Sept. 17	18	22	2·6
Last „	„	20	1	34·3

The Sun being hidden from the $4\frac{1}{2}$-inch Equatoreal by the house and trees, the eclipse was observed by means of the $3\frac{1}{4}$-inch portable refractor armed with a power of ninety and a green shade. The position of the telescope was about sixty yards east

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of the Observatory. Notwithstanding a careful scrutiny, I did not succeed in observing the thorn-like projections of light seen on the solar cusps by Captain Noble and others during the eclipse of September last. The eclipse, which was equal to about one-third of the Sun's diameter, had an interesting effect on a black-bulb thermometer enclosed in an exhausted glass globe.

Windsor, New South Wales,
1876, *Sept.* 21.

Observations of the Lunar Eclipse, 1876, *September* 3, *made at Cadiz.* By Augusto T. Arcimis.

At 7^h I commenced the observations. The state of the atmosphere was magnificent, not a single cloud was visible above the horizon, nor was the slightest breeze perceptible, the sky having an extraordinary and exceptional purity. To the west were visible the last glimmers of the twilight. I made use of a 4-inch refractor (by Secretan of Paris), with an astronomical eyepiece, of the power of 92 diameters. To sketch the projection of the terrestrial shadow I employed a reduced map of the Moon of Beer and Mädler and some photographs of Mr. Warren De La Rue, which I kept constantly before me.

The hours are according to Cadiz mean time; the geographical co-ordinates of my observatory are:

Lat. N. $= 36^\circ\ 31'\ 52''{\cdot}8$;

Long. W. Greenwich $= 0^h\ 25^m\ 11^s{\cdot}7$.

At $7^h\ 15^m$ I saw the penumbra which concealed the Oceanus Procellarum, Mare Imbrium, Sinus Æstum, and Mons Carpathus.

At $7^h\ 40^m$ I could see with the naked eye that the light was scarce in the NE. quadrant (invert. vis.) and took a reddish tint.

At $7^h\ 50^m$ (hour of the first contact) the shadow reached the peak Cleostratus (although of the precise moment I am somewhat doubtful), and enlarged itself rapidly to Mons Harpathus and Sinus Proris. Five minutes later I could see with great facility the shadow with the naked eye.

I then applied the spectroscope to the refractor, directing it to the crater Lavoisier; the common solar spectrum appeared as it was expected, but as the shadow advanced and the light became fainter, I detected some of the absorption lines on the red, produced by the Earth's atmosphere.

At $8^h\ 5^m$ the limits of the shadow are, to the east, 38° lat. N., craters Lavoisier, Mairan, Plato, Archytas, Mayer; and ends to the west in 82° lat. N.

I applied again the spectroscope, and in the

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darkest part of the lunar disk the spectrum was little visible on account of want of light, but near the limits of the shadow I found the telluric lines on the red, between D and F, and above all between F and C, where they became very numerous.

At 8^h 20^m the limit of the shadow crossed the 28° lat. N., on the east, craters Briggs, Diophantus, on the middle of Mare Imbrium, crater Autolycus, Palus Nebularum, crater Burg, Lacus Mortis, crater Endymion, and ends to the west in 60° lat. N.

At 8^h 32^m the shadow reaches the crater Aristarchus; this was its highest point, on the NE. quadrant.

At 8^h 41^m the light appeared again upon this crater, and the shadow pursued its descending path.

At 8^h 50^m the shadow is bounded to the east by 34° lat. N., crater Euler, Mons Apenninus, Hœmus, crater Macrobius, the boreal edge of Mare Crisium, and finished to the west by 30° lat. N.

At 8^h 57^m time of the middle of the eclipse, according to the Ephemeris, and the shadow begun to the east by 36° lat. N., craters Euler, Manilius, on the middle of Mare Vaporum, crater Vitruvius, and ends to the west by 22° lat. N.

At 9^h 6^m the limits were, to the east, 40° lat. N., craters Diophantus, Euler, Pytheas, Manilius, Palus Somnii, crater Picard in Mare Crisium, and ended to the west in 18° lat N.

The neighbourhood of the boreal pole which was the darkest, had an orange colour, and the other parts of the shadow were of a livid white, similar to the light of *Saturn*.

I made another analysis with the spectroscope; some of the telluric lines on the violet had disappeared, but those on the red remained very visible.

At 9^h 24^m the shadow is bounded to the east by 56° lat. N., craters Cleostratus, Sharp, somewhat to the north of Archimedes, Palus Putredinis, craters Menelaus, Jansen, Condorcet, and ends to the west in 12° lat. N.

At 9^h 49^m the limits are, to the east, 66° lat. N., craters Pythagoras, La Condamine, at half the distance of Harpathus and Senopidus, on the middle of Mare Serenitatis, crater Proclus, Mare Crisium, crater Agarum, and ends to the west by 16° lat. N.

At 10^h 4^m the last contact took place, with the shadow very near Mare Humboldtianum by 53° lat. N. on the NO. quadrant.

It seems to me that I can point out a small difference in this last contact between the observation and the Ephemeris; those which I have made use of are published here under the title of *Nautical Almanac*.

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Observations of Minor Planets with the Transit-Circle at Dublin (Dunsink).

(Communicated by Dr. Robert S. Ball.)

(9) *Metis.*

1875.	Mean Time, Dublin.	α (App.)	δ (App.)	Par.	Obs.—Eph. Δα	Obs.—Eph. Δδ	Mag.	Remarks.
	h m s	h m s	° ′ ″	″	s	″		
Sept. 10	12 54 12	0 12 50·12	− 8 59 44·6	+6·1	−2·46	−14·8	...	
„ 11	12 49 25	0 11 59·61	− 9 5 37·1	+6·1	−2·27	−16·1	9·0	
„ 12	12 44 38	0 11 7·77	− 9 11 28·2	+6·1	−2·49	−18·0	9·0	
„ 13	12 39 50	0 10 15·50	− 9 17 13·1	+6·1	−2·29	−16·3	9·1	
„ 20	12 5 54	0 3 59·72	− 9 55 43·2	+6·2	−2·44	−16·1	8·6	Reddish; certainly far redder than [*Eurydice.*
„ 28	11 26 52	23 56 13·81	−10 32 51·3	+6·3	−2·31	−15·5	9·0	Blue.

(75) *Eurydice.*

Sept. 10	12 41 7	23 59 43·04	− 1 22 57·0	+8·3	+1·06	+ 7·9	9·6	
„ 11	12 36 23	23 58 55·52	− 1 22 57·8	+8·3	+1·10	+ 6·2	10·2	
„ 12	12 31 39	23 58 7·15	− 1 23 0·4	+8·3	+0·98	+ 5·3	9·6	
„ 13	12 26 55	23 57 18·30	− 1 23 2·7	+8·3	+0·99	+ 7·0	9·5	Moon near; very faint.
„ 20	11 53 33	23 51 27·12	− 1 24 12·1	+8·2	+0·87	+ 7·3	8·8	Bluish.

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(111) *Ate.*

1875.	Mean Time, Dublin h m s	α (App.) h m s	δ (App.) ° ′ ″	Par. ″	Obs.—Eph. Δα s	Obs.—Eph. Δδ ″	Mag.	Remarks.
Nov. 7	11 54 43	3 1 51·85	+25 38 13·5	+2·8	+3·59	− 9·7	...	
„ 11	11 34 59	2 57 51·20	+25 21 5·5	+2·9	+3·59	− 8·4	10·1	

(97) *Clotho.*

Nov. 11	11 59 57	3 22 53·29	− 3 23 59·2	+7·2	+8·03	+26·8	...	
„ 14	11 45 54	3 20 37·71	− 3 41 58·7	+7·2	+8·22	+26·3	9·1	

(13) *Egeria.*

Nov. 7	12 25 1	3 32 14·51	+23 29 37·4	+3·0	+1·17	+ 6·7	...	

The Right Ascensions are based on the *Greenwich Catalogue* for 1864·0, and the Declinations on the Catalogue of the *Vierteljahrschrift* of the "Astronomische Gesellschaft." The comparisons have been made with the Ephemerides of the *Berliner Jahrbuch*. The observations were made by Dr. R. Copeland.

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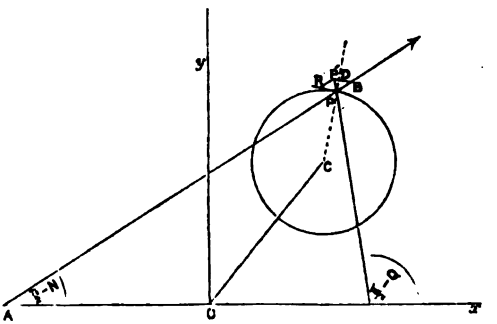
A Method of deducing the Formula for correcting the computed Time of an observed Occultation for Errors in the Elements adopted.

By W. H. Finlay, B.A., First Assistant, Cape Observatory.

In Bessel's method of computing occultations the positions of the Moon and observer are referred to three axes at right angles to one another through the centre of the Earth: of which the axis of z is directed to the star (R.A. $= \alpha'$, Declination $= \delta'$), the axis of x to the point in the equator whose R.A. is $90° + \alpha'$, and the axis of y to the point in the declination-circle through the star whose distance from the equator is $90° + \delta'$. When the occultation takes place the projection of the place of observation on the plane of xy lies on the circumference of the projection of the Moon's disk. Let the figure represent the projection on the



plane xy of the Moon's disk at the time T, and let P be the projection of a place at which the occultation is taking place. Let P′ be an adjacent point in the plane: through P and P′ draw lines parallel to the projected direction of motion of the Moon's centre at the time T, and draw PR touching the circle at P. Then if PP′ be small, P′R is approximately the distance that the Moon's projection must pass through before the point P′ is on the circumference. Draw P′B parallel to the tangent at P, cutting CP produced in D. Let PP′ $= d$, and the angle PP′ makes with the axis of $x = 90° - Q$.

With Chauvenet's notation the angle PA$x = 90° - N$, angle CPB $= \psi$; and the Moon's relative velocity in its projected path is u,—the unit of length being the equatoreal radius of the Earth and of time one mean hour.

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Now, from the figure—

$$PP' \cos DPP = PD = BP \cos BPD,$$

that is $PP' \cos (BPP' - BPD) = P'R \cos BPD$;

or $d \cos \{N - Q - (180° - \psi)\} = P'R \cos (180° - \psi)$;

$$\therefore P'R = \frac{d \cos (N - Q + \psi)}{\cos \psi};$$

and the time of Moon's projection describing $P'R = \frac{P'R}{n}$. If P′ be the projection of a point on the Earth's surface not far distant from P, the time at which the occultation takes place at this second station will be approximately $T \pm \frac{P'R}{n}$. A paper on this case by the Rev. T. Chevallier, B.D., will be found in Vol. XIX. of the *Memoirs*. Now consider the case in which the projection of the Moon's centre undergoes slight changes of position owing to slight changes in the elements. These changes may for convenience be attributed to the point P with opposite signs. A slight change common to both Moon and star has scarcely any effect, so we need only consider relative changes.

(i.) If the relative increase of R.A. of the Moon and star be $\Delta (\alpha - \alpha')$, then, π denoting the Moon's parallax, the Moon's centre will be moved through an arc equal to $\frac{\Delta (\alpha - \alpha') \cos \delta}{\sin \pi} \times$ circular measure of 1″, perpendicular to the plane zy; therefore, in this case, PP′ is equal to $\frac{\Delta (\alpha - \alpha') \cos \delta}{\pi}$ and parallel to xO, that is $Q = 90°$.

$$\therefore P'R = -\frac{\Delta (\alpha - \alpha') \cos \delta}{\pi} \cdot \frac{\sin (N + \psi)}{\cos \psi}.$$

(ii.) Let $\Delta (\delta - \delta')$ be the relative increase of declination. Here PP′ is equal to $-\frac{\Delta (\delta - \delta')}{\pi}$ and parallel to yO, that is $Q = 0$.

$$\therefore P'R = -\frac{\Delta (\delta - \delta')}{\pi} \cdot \frac{\cos (N + \psi)}{\cos \psi}.$$

(iii.) Let $\Delta\kappa$ be the increase of the Moon's radius. Then P′ is on the line APB, that is $Q = N$.

$$\therefore P'R = PP' = \frac{-\Delta\kappa}{\cos (180 - \psi)} = \frac{\Delta\kappa}{\cos \psi}.$$

(iv.) Let $\Delta\pi$ be the increase in the Moon's parallax. Put $OC = R$ and angle $COx = 90° - \theta$: then from this change C moves towards O a distance ΔR.

Now $R = \frac{a}{\sin \pi}$ where a is independent of π.

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$$\therefore \frac{\Delta R}{R} = -\frac{a\cos\pi}{\sin^2\pi}\cdot\frac{\sin\pi}{a}\Delta\pi \times \text{circ. meas. of } 1'' = -\frac{\cos\pi}{\pi}\cdot\Delta\pi,$$

$$\therefore PP' = -\Delta R = \frac{R\cos\pi}{\pi}\cdot\Delta\pi, \text{ and } Q = \theta,$$

$$\therefore P'R = \frac{R\cos\pi.\Delta\pi}{\pi}\cdot\frac{\cos(N+\psi)\cos\theta+\sin(N+\psi)\sin\theta}{\cos\psi}$$

$$= \frac{\cos\pi.\Delta\pi}{\pi}\cdot\frac{y\cos(N+\psi)+x\sin(N+\psi)}{\cos\psi},$$

where x and y are the co-ordinates of the Moon's centre at the time T.

Since these small changes are independent of one another, their combined effect will be equal to their sum.

$$\therefore \left.\begin{matrix}\text{total correction to the}\\ \text{time T in seconds}\end{matrix}\right\} = \frac{\text{sum of the several values of P'R}}{n}\times h,$$

where h is the number of seconds in the unit of time; that is

$$\text{correction} = -\frac{h}{n\pi\cos\psi}[\sin(N+\psi)\cos\delta.\Delta(\alpha-\alpha')+\cos(N+\psi)\Delta(\delta-\delta')$$
$$+\pi.\Delta\kappa-\{x\sin(N+\psi)+y\cos(N+\psi)\}\cos\pi.\Delta\pi],$$

which is the usual formula, omitting the terms depending on error of eccentricity of the meridian.

1876, *July*.

On the Effect of Wear in the Micrometer-Screws of the Greenwich Transit-Circle. By W. H. M. Christie, Esq.

It has been the practice of observers to examine carefully the accuracy of micrometer-screws on receiving them from the maker's hands; but no one, so far as I am aware, has considered it necessary to make any observation afterwards, though the effect of wear, when observations are made frequently, soon becomes sensible. Under these circumstances, it may be desirable to give an account of a case in which considerable errors have been caused by continued use during a period of more than twenty years.

The wear in the micrometer-screws of the Greenwich Transit-Circle first showed itself by a discordance between the Zenith-points deduced from the Nadir observation and from Stars respectively; though the cause was not suspected till the beginning of 1875, when a change in the position of the division in the field of view of the micrometer-microscopes was found to be accompanied by a change in the discordance from $+0''.7$ to $-0''.6$. This discordance first became sensible in the year 1868; but the error in the

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screws, as will be seen presently, existed certainly before that time, though its effect on the Nadir observation was insensible so long as the observations were distributed over the whole range of the screws. This was the case up to 1868, after which the system was altered, the Nadir observation being from that time made with the circle-divisions at 0^r approximately. When the change in the discordance occurred at the beginning of 1875, the values of successive revolutions of the telescope-micrometer, and also of the microscope-micrometer-screws were tested by means of the collimator, and it was found that there was considerable inequality in the latter. To obtain the corrections applicable to the different parts of the screws, four supplementary microscopes (which had only been used occasionally for determining the division-errors of the circle) were mounted and read for comparison with the six ordinary microscopes. These observations are printed in the *Greenwich Observations*, 1875. From 457 comparisons thus made, the continuous curve shown in the diagram has been laid down, the means of the separate apparent corrections tabulated for every tenth of a revolution having been smoothed by taking the means for each adjacent pair, and then the means of these results again in the same way. The ordinates give the corrections to the circle-reading corresponding to the revolutions and tenths of Microscope A, indicated above, which has been taken for convenience of application. Its readings were throughout $0^r.13$ less than the mean of the six micrometer-readings.

In 1868 similar observations had been made, though with a different object in view, namely, to determine the probable value of the outstanding division-error of the circle. They are, however, equally available for testing the revolutions of the micrometer-screws, and from 289 comparisons thus made, the corrections applicable in 1868 have been found. These are represented by the dotted curve, formed in the same way as that for 1875, but with the origin shifted $0^r.08$ to the left, since Microscope A in 1868 read on the average $0^r.05$ less than the mean. The revolutions and tenths of Microscope A for the 1868 curve are given below. Both curves are thus virtually referred to the mean of the micrometer-readings. It will be remarked that the two curves are generally similar, giving large positive corrections for the middle of the range; but that the curve for 1868 falls above that for 1875, the corrections being on the whole positive. In fact, the mean of all the individual observations of discordance in 1868 is $+0''.20$, whilst in 1875 it is $+0''.09$. As these quantities considerably exceed the probable error of the result, which would be about $0''.03$, it is possible that some systematic error, such as a difference in the outstanding division-error for the parts of the circle used in finding the Zenith-point with the ordinary and supplementary microscopes respectively, may have affected all the observations. This, however, does not interfere with the comparison of the

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two curves, as the ordinates may be supposed reduced throughout by + 0″·20 and + 0″·09 in the two cases respectively. There is another point of difference between the two curves, which depends on the adopted correction for runs, and has the effect of making the axis of symmetry fall somewhat to the left in the dotted curve, which consequently lies above the other at 0ʳ, and falls below it at 5ʳ. Now the wear will take place on the part of the thread against which the spring presses the hollow screw of the micrometer slide, and the cross-wires will consequently be carried further from the head, that is in the direction of increasing readings. Thus, for any given position of the cross-wires, the head will give too small a reading, and a positive correction will therefore be required, this correction being larger for the middle of the range of the screw, which is the part most frequently used. One effect of this will be to increase the run, if the error at the large reading (4ʳ·9 approx.) be greater, algebraically, than that at the small reading (0ʳ approx.), and the same will apply to the correction for runs if corrections be substituted for errors. Now the corrections increase (algebraically) from negative to small positive readings, and decrease from large positive readings onwards, and thus the correction for runs will be greater (algebraically) when the small reading is taken on the negative side of the zero than when it falls on the positive side. In the former case the corrections for error in the screws will be algebraically increased for small readings and decreased for large readings by application of the correction for runs; and this effect is purely arbitrary, since we may choose any part of the screw for zero.

Making due allowance for this, and also for the difference in the sums of all the corrections for the two sets, the dotted curve must be lowered 0″·4 approximately at 0ʳ, and raised 0″·2 at 5ʳ, proportional changes being made for intermediate readings. The agreement between the two curves will then be remarkably close, except for the portion between 0ʳ and 1ʳ, at which point the 1875 curve rises very abruptly, indicating that considerable wear has taken place in that part since 1868. This appears to be fully accounted for by the circumstance that in that year the practice was commenced of taking the Nadir observation with the circle-division at 0ʳ approximately; and, as the observation is regularly made twice a day, there would be a preponderance of some 4,000 observations at this part of the screw in the course of the eight years elapsed since 1868.

It would thus appear that by far the greater portion of the wear in the micrometer-screws has taken place in the seventeen years preceding 1868, and that, except in the part between 0ʳ and 1ʳ, the errors have not sensibly changed since that date. On comparing the several tenths of any one revolution, the corrections for ·7, ·8, and ·9 would appear to be about 0″·2 smaller (algebraically) than the others, but the difficulty of eliminating the effect of the larger corrections is considerable, and the quantities are too small to be determined with certainty.

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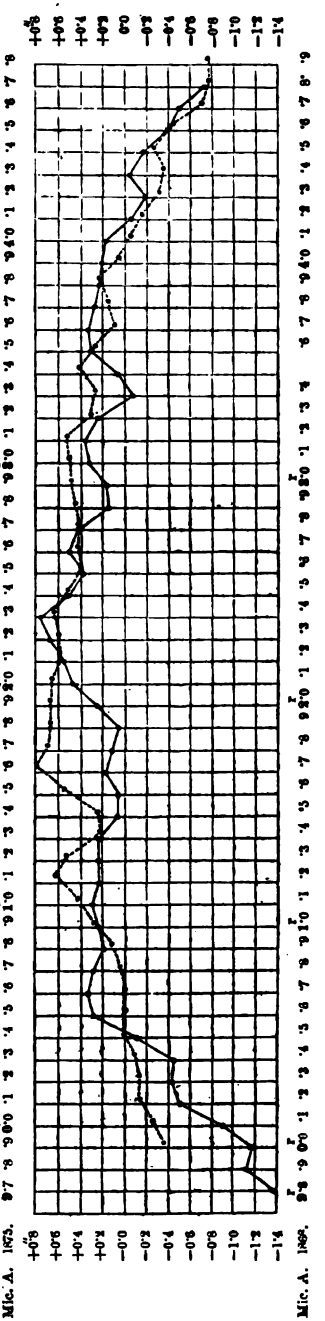

Corrections to Micrometer-Screws of Greenwich Transit-Circle, 1868 and 1875.

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The corrections thus found are considerable; and it is to be remarked that they are of the nature of systematic errors, affecting all the observations of any one star, which would usually be observed in the same part of the field of view of the telescope, and therefore, for several years, with the circle-division about the same part of the range of the micrometer-screw. This points to the necessity for periodic examination of micrometer-screws, though the effect of wear will be sensibly eliminated if the action of the spring be in opposite directions for every pair of micrometers, the readings increasing towards the head for one micrometer, and from the head for the other of each pair.

It may be proper to add, that the accuracy of the screws of the four supplementary microscopes has been tested indirectly by comparison with new screws applied to the six ordinary microscopes, as well as directly by observations on the collimator.

Royal Observatory, Greenwich,
1876, *Nov.* 9.

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*Spectroscopic Results for the Motions of Stars, and of Venus in the Line of Sight, and for the Rotation of the Sun and of Jupiter, made at the Royal Observatory, Greenwich. II.**

(*Communicated by the Astronomer Royal.*)

The recent results for Star-motions have been obtained in the same manner as those given in the *Monthly Notices* for last May, and the general arrangement is unaltered. As, however, it has been suggested by P. Secchi that the results may possibly be dependent on the position of the spectroscope, the reading of the position-circle (or the position-angle of the slit) is here added. The slit lies north and south, and the deviation of the ray is towards the east when the reading is 0°. This is the most convenient position, and is that in which most of the observations have been made. In the earlier measures made in 1874 observations were taken in each of the four quadrants; but, as the position of the spectroscope did not appear to affect the result, the practice was discontinued. All the observations since then are therefore strictly comparable in this respect, and all stars would be equally affected by any error depending on the position of the spectroscope. As a check on the absolute values, however, some measures of the lines in the spectrum of the Moon and of *Venus* have been made in different positions. Special care has been taken to observe the stars in pairs east and west as far as practicable, so that the Earth's motion might affect the several observations with different signs, and also that any error depending on the position of the instrument might be eliminated.

The means have been taken for the whole series of observations of each star, including those given in the *Monthly Notices*

* The Results for the Rotation of the Sun and of *Jupiter* will be given in the *December* number.—[Ed.]

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for last May. Where no mean is set down, the result is to be considered as still uncertain. Sufficient observations have now been accumulated to allow of a fair estimate of the probable error in different cases being made. This depends far more on the character of the line observed than on the brightness of the star, being least for those stars which show well-defined lines, such as the *b* group; whilst for stars such as *Altair*, in which the F-line is very broad and nebulous, the uncertainty is so great as to make the spectroscopic method quite inapplicable. It may be remarked, that the range to be expected in a group of observations is five or six times the probable error, so that with a probable error of 10 miles a second the extreme discordance between individual results might be expected to reach 50 or 60 miles a second. P. Secchi would appear to have overlooked this consequence of the theory of errors of observation. The stars have been grouped together, according to the character of their spectra, for the determination of the probable errors in cases where there were less than eight observations. The probable errors of the results are appended with the sign $\pm$.

The measures of the displacement of the lines in the spectrum of the Moon and *Venus* have been made to test both the accuracy of the method of observation and the truth of Döppler's principle. In the case of the Moon, the motion in the line of sight is insensible, and the result of the observations shows a very satisfactory agreement with this. The motion of *Venus* has been observed at both elongations, the comparison being made in some cases with the bright lines of hydrogen or magnesium, in others with the sky spectrum. The observations at the western elongation were made in the forenoon. The calculated motions have been deduced from the daily change of the distance from the Earth, as given in the *Nautical Almanac*. It will be remarked, that the observed motion is rather larger than the calculated, both for the approach and recession; this may be due in part to the disturbing effect of the juxtaposition of two nearly coincident lines. The discordance, however, is small, and may well be a mere chance error in each case; at any rate, as it has the same sign as the motion, it serves to show that there is no systematic error. Generally, the direction of the displacement to be expected was not known to the observer at the time of making the observation.

In measuring the Rotation of the Sun, the great point aimed at was to prevent the Sun's heat from in any way affecting the position of the line observed, by expanding the slit unsymmetrically. Several precautions were adopted to guard against this, and with perfect success, as the measures show. In the first place, a tin screen, perforated with a small hole, 0·2 inch in diameter, was placed three inches in front of the slit, from which it was separated by non-conducting material. When this had been applied, as well as a diaphragm, with a hole of $\frac{1}{50}$ inch close

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to the slit, no perceptible rise of temperature in the slit could be detected, a very small portion only being exposed to the Sun's rays. Further, the slit was always placed radially on the Sun's limb, so that the Sun's heat might affect the two sides equally; and, lastly, the slit was placed *alternately* on the east and west limbs, by use of the slow-motion in R.A., and not by allowing the diurnal motion to carry the Sun's image across the slit. By this plan the change from one limb to the other was made so rapidly that no sensible disturbance could take place in the interval; and, further, the observations were made in a continuous series. One set of measures of the east and west limbs, and another of the north and south are given as specimens. The observations were made in the order of numeration. The north and south limbs were compared in exactly the same manner as the east and west limbs, with the slit radial, as a check on the system of observation; but no great care was bestowed on the determination of the position-angle on the Sun's limb, which may be many degrees in error, as it was not easy to verify this point. The observations, however, suffice to show that the precautions adopted have removed the sources of error to which results by former observers appear to have been exposed. Particular care was taken to avoid any bias from previous knowledge of the direction in which a displacement was to be expected, the limb under observation not being determined till after the bisection had been made. In the calculated motion there is some uncertainty, as it is doubtful how far the period of rotation deduced from Sun-spots will apply to the chromosphere, to the rotation of which the observed displacement is due. There would appear to be no reason to suppose that it takes part in the general drift depending on the latitude which has been remarked in Sun-spots.

Many attempts were made to measure the displacement of the F-line due to the rotation of *Jupiter*, but for a long time they were frustrated by the prevalence of haze near the horizon, the planet having large southern declination. On one occasion, however, the spectrum was seen fairly well, and some measures obtained which give a result in remarkable agreement with the calculated value. It is to be remarked, that the method can be applied to *Jupiter* with peculiar advantage, as the equatoreal velocity is very large, and its effect doubled by reflexion. Thus the observed displacement corresponds nearly to four times the equatoreal velocity.

The velocity of light has been taken as 185,000 miles a second, and the distance of the Sun as 91,260,000 miles.

Royal Observatory, Greenwich,
1876, *Nov.* 10.

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Motions of Stars in the Line of Sight in Miles per Second. II.

(+ denotes Recession; − Approach.)

1 div. in the width of the slit corresponds to 0·0013 inch; the weights are on a scale 1–5 for *each* observation; the Means have been taken for the whole series of observations, including former results.

The initials WC and M are those of Mr. Christie and Mr. Maunder respectively.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
					°	d					
						γ Leonis.					
1876 May 15	M	1	2	2	0	2·0	b_4	+17·7	−57·3	−44·3	Indirect comparison; star-lines not very distinctly seen.
15	M	2	6	2	0	2·7 & 1·5	b_1	+17·7	−53·8	−57·2	Indirect comparison; the lines in this spectrum are narrow and sharp.
								Mean	−63·5 ± 7	−60·2 ± 6	
								Probable error of 1 determination	13	10	
						β Ursæ Majoris.					
1876 May 19	WC	1	2	2½	0	3·0	F	+12·3	+52·7	+45·5	Indirect comparison; star-line only seen distinctly for an instant.
								Mean	+23·8 ± 9	+22·1 ± 7	
								Assumed probable error of 1 determination	13	10	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							Arcturus.				
					°	d					
1876 May 13	M	2	10	2½	0	2·5 & 2·3	b_1	+ 7·9	−33·2	−53·8	Direct comparison; definition very good.
29	WC	2	6	2½	...	1·2	b_1	+11·1	−52·7	−44·6	Direct comparison.
30	M	2	4	2½	0	1·4 & 1·7	b_1	+11·2	−32·7	−25·6	Ind.comp.; image very tremulous; much mist.
July 14	M	3	10	2½	5	3·2 & 2·0	b_1	+15·3	−45·5	−61·7	Indirect comparison; lines not well seen; image tremulous.
17	M	2	4	2½	5	2·1	b_1	+15·3	−38·4	−37·0	Indirect comparison.
24	M	2	8	2½	5	2·6	F	+15·1	−38·2	−52·6	Indirect comparison.
								Mean	−38·3 ± 2·1	−44·5 ± 2·8	
						Probable error of 1 determination			6·7	8·9	
							e² Boötis.				
1876 May 13	M	2	10	2½	0	1·6	b_1	+ 6·2	− 6·7	− 9·2	Indirect comp.; star-lines very well defined.
29	WC	3	3	2½	...	1·7 & 2·6	b_1	+ 9·1	+22·0	− 1·7	Indirect comparison; star-line very faint, but sharp and distinct.
July 26	M	2	4	2½	5	1·8	b_1, b_4	+13·4	+26·2	+25·6	Indirect comparison.
								Mean	+ 4·1 ± 6	− 2·3 ± 5	
						Probable error of 1 determination			13	10	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							α Coronæ.				
					°	d					
1876 July 24	M	2	6	2½	5	3·1	F	+ 12·6	+ 31·7	+ 41·2	Indirect comparison; star-line broad, dark in the centre, but diffused at the edges.
Aug. 16	M	2	6	1½	5	2·2	F	+ 12·4	+ 36·4	+ 37·3	Indirect comparison.
							Mean		+ 36·0 ± 10	+ 39·7 ± 8	
							Probable error of 1 determination		17	14	
							β Herculis.				
1876 July 12	M	2	3	2½	5	2·3	b_1	+ 10·2	− 59·4	− 57·3	Indirect comp.; star-lines very difficult to see.
							Assumed probable error of 1 determination		13	10	
							α Herculis.				
1876 July 12	M	2	2	2½	5	1·5	b_4	+ 8·4	− 15·5	− 14·4	Ind. comp. { Star-line well defined towards the blue, but easily confused with others towards the red.
17	M	2	3½	2½	5	3·2 & 2·2	b_4	+ 9·3	− 37·0	− 42·4	Ind. comp. { Star-line well defined towards the blue, but easily confused with others towards the red.
							Mean		− 29·2 ± 12	− 32·2 ± 10	
							Assumed probable error of 1 determination		17	14	
							β Draconis.				
1876 July 26	M	2	1	2½	5	2·0	b_1, b_4	+ 3·7	+ 12·5	+ 10·9	Indirect comp.; star-lines very indistinct.
Aug. 12	M	1	½	2½	5	2·1	b_1	+ 4·3	− 1·8	− 4·3	Indirect comp.; star-line very difficult to see.
							Mean		+ 7·7 ± 12	+ 5·8 ± 10	
							Assumed probable error of 1 determination		17	14	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							α Ophiuchi.				
1876 June 26	M	2	3	2½	° 0	d 1·1 & 1·7	F	+ 3·7	+ 9·0	+ 9·4	Ind. comp.; image very faint and tremulous.
July 8	M	2	6	2½	4½	2·0 & 3·5	F	+ 6·4	−12·4	−14·8	Indirect comparison; star-line wide and somewhat indistinct.
22	M	2	5	2½	5	2·8	F	+ 9·2	+31·5	+22·5	Indirect comparison; star-line almost as wide and indistinct as that in *Altair*.
								Mean	+ 3·6 ± 8	+ 0·1 ± 7	
						Probable error of 1 determination			17	14	
							γ Draconis.				
1876 July 17	M	2	4	2½	5	1·5	b_4	+ 2·3	−21·6	−32·5	Ind. comp.; star-lines (b) rather wide & dark.
26	M	3	7	2½	5	2·1	b_4, b_1	+ 2·8	−12·9	−13·2	Indirect comparison.
Aug. 25	M	2	2½	2½	...	1·5 & 1·3	b_1	+ 4·3	−23·2	−19·8	Indirect comparison.
25	WC	1	1	2½	...	2·5	b_1	+ 4·3	−12·5	−16·7	Indirect comparison.
								Mean	−17·1 ± 6	−19·9 ± 5	
						Probable error of 1 determination			13	10	
							α Lyræ.				
1876 June 26	M	2	7	2½	0	2·1 & 0·5	F	− 1·2	−33·4	−18·7	Indirect comparison.
								Mean	−38·5 ± 2·7	−34·0 ± 3·2	
						Probable error of 1 determination			9·0	10·6	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							ζ Aquilæ.				
					°	d					
1876 July 24	M	2	5	1½	5	2·0	F	+ 3·5	+41·0	+26·5	Ind. comp. } Star-line broad, dark, but not
Aug. 14	M	2	6	1½	5	2·0	F	+ 6·4	+42·4	+34·8	Ind. comp. } ill defined.
								Mean	+41·8 ± 9	+31·0 ± 7	
						Assumed probable error of 1 determination			13	10	
							γ Aquilæ.				
1876 July 14	M	2	1	2½	5	2·0 & 1·9	b_1	− 1·7	−31·0	−30·0	Ind. comp.; almost too faint for observation.
						Assumed probable error of 1 determination			17	14	
							δ Cygni.				
1876 July 24	M	2	7	1½	5	2·9 & 2·5	F	− 1·6	−29·6	−32.7	Ind. comp. } Star line dark, somewhat broad,
Aug. 14	M	2	5	1½	5	1·7	F	+ 1·0	− 7·9	−14·1	Ind. comp. } and fairly defined at the edges.
								Mean	−20·6 ± 12	−25·0 ± 10	
						Assumed probable error of 1 determination			17	14	
							Altair.				
1876 June 26	M	2	5	2½	0	0·7 & 1·2	F	− 6·4	−31·0	− 8·5	Indirect comparison; definition poor.
July 8	M	4	15	2½	4½	2·5 & 2·6	F	− 3·5	+35·1	+24·4	Indirect comp.; observations discordant.
						Probable error of 1 determination			46·6	36·3	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
						γ Cygni.					
					°	d					
1876 July 8	M	3	6	2½	4½	1·9	F	− 5·7	− 4·2	− 5·3	Indirect comparison.
12	M	2	6	2½	5	1·8	b_4	− 5·2	−31·4	−28·9	Indirect comparison.
14	M	2	4	2½	5	1·9	b_1, b_4	− 4·9	−32·7	−38·4	Indirect comparison.
17	M	2	4½	2½	5	1·6	b_1, b_4	− 4·5	−18·6	−19·5	Ind. comp.; b_4 seems the easier line to bisect.
26	M	1	2	2½	5	2·6	b_1	− 3·1	−10·2	−14·9	Indirect comparison.
31	M	2	2	2½	5	1·8	b_1	− 2·3	−16·5	−12·3	Indirect comparison; spectrum tremulous, and star-lines confused.
							Mean		−19·7 ± 3	−20·4 ± 4	
							Probable error of 1 determination		8	9	
						α Cygni.					
1876 July 8	M	2	8	2½	4½	1·8 & 2·6	F	− 6·5	−37·7	−35·9	Indirect comparison.
12	M	2	6	2½	5	1·0 & 0·6	b_1	− 6·1	−25·0	−13·2	Indirect comparison.
14	M	2	5	2½	5	2·5	b_1, b_4	− 5·8	−21·7	−43·7	Indirect comparison.
							Mean		−40·2 ± 3	−41·4 ± 3	
							Probable error of 1 determination		8	9	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							ε Cygni.				
					°	d					
1876 July 17	M	2	2½	2½	5	1·6	b_1, b_4	− 5·9	+ 7·5	+ 10·5	Indirect comparison; almost too faint a star to observe.
Aug. 12	M	2	1	2½	5	2·1	b_1	− 1·1	+ 22·4	+ 25·9	Indirect comparison; star-line very faint and difficult to see.
							Mean		+ 11·8 ± 9	+ 14·9 ± 7	
							Assumed probable error of 1 determination		13	10	
							ε Pegasi.				
1876 July 12	M	3	6	2½	5	2·5	b_1, b_2, b_4	− 10·4	− 27·5	− 27·1	Indirect comparison.
31	M	2	2	2½	5	1·3	b_1	− 5·9	− 26·8	− 14·7	Indirect comparison; spectrum faint, but definition fair.
Aug. 12	M	2	2	2½	5	1·5	b_1	− 2·7	− 12·1	− 14·0	Indirect comparison; spectrum faint.
23	M	2	1½	1½	5	2·0	b_1	+ 0·3	− 28·4	− 27·5	Indirect comparison; star-line faint and somewhat indistinct.
							Mean		− 24·8 ± 4	− 22·7 ± 4	
							Probable error of 1 determination		8	9	
							Fomalhaut.				
1876 July 24	M	3	7	1½	5	3·1	F	− 8·2	+ 19·2	+ 23·9	Indirect comparison; star-line dark, somewhat broad, and edges fairly sharp.
Aug. 14	M	2	2	1½	5	2·3	F	− 2·8	− 18·1	− 19·8	Indirect comp.; star-line not well defined.
							Assumed probable error of 1 determination		13	10	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							β Pegasi.				
					°	d					
1876 July 31	M	3	6	2½	5	1·8	b_4	−11·4	+16·5	+17·3	Indirect comparison; star-line not easily isolated from others near.
Aug. 12	M	2	4	2½	5	1·6	b_4	− 9·2	+23·7	+26·6	Indirect comp.; light cloud; wind high.
							Mean		+19·4 ± 9	+21·0 ± 7	
							Assumed probable error of 1 determination		13	10	
							α Pegasi.				
1876 Aug. 14	M	2	4	1½	5	2·2	F	− 8·2	− 2·2	− 6·0	Indirect comp.; image rather unsteady.
							Mean		−24·8 ± 8	−18·5 ± 7	
							Probable error of 1 determination		17	14	
							Moon.				
1876 May 29	WC	1	3	2½	...	1·7	b_1	...	− 4·1	...	Moon-line rather faint.
29	WC	1	3	2½	...	2·0	b_1	...	+ 5·1	...	Moon-line rather faint.
30	M	1	1	2½	0	...	b_1	...	−10·8	...	Moon-line hardly visible.
30	M	1	2	2½	0	...	b_1	...	− 5·5	...	Moon-line seen a little better.
30	M	1	2	2½	0	...	b_1	...	− 7·1		
30	M	1	2	2½	0	...	b_1	...	+11·2		

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							Moon—continued.				
Nov. 1	M	1	2	2	62°	2·0	F	...	+18·6	...	Definition very variable; Moon-line seen fairly well.
1	M	1	2	2	62	1·8	F	...	+ 8·2	...	Moon-line seen fairly well.
1	M	1	1	2	62	1·8	F	...	−10·4	...	Moon-line not so well seen.
1	M	1	3	2	62	5·0	F	...	−18·6	...	Both the Moon- and comparison-spectrum seen well.
1	M	1	3	2	62	3·2	F	...	− 2·9	...	Both the Moon- and comparison-spectrum seen well.
								Mean	+ 0·6 ± 1·2		
							Probable error of 1 observation		6·0		
							Venus.				
1876 May 16	M	1	2	2	0	6·5	F	...	−14·0	...	Planet's spectrum faint.
16	M	1	2	2	0	1·6	F	...	−11·5	−13·8	Indirect comp.; planet's spectrum faint.
16	M	1	2	2	0	1·6	F	...	−22·1	−13·8	
19	WC	1	1	2½	0	1·9	F	...	−24·2	−12·9	Indirect comparison.
19	WC	1	2	2½	0	1·8	F	...	−14·9	−18·5	
19	WC	1	3	2½	0	2·1	b_1	...	−12·3	−24·8	Direct comp.; planet's lines fairly well seen.
29	WC	1	4	2½	...	1·7	b_1	...	−19·6	−14·7	
29	WC	1	2	2½	...	0·4	b_1	...	−19·2	−14·7	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							Venus—continued.				
					°	d					
May 30	M	1	3	2½	0	0·5	b_1	...	− 6·5	− 4·1	Indirect comparison; planet's spectrum faint; wind high.
30	M	1	2	2½	0	0·5	b_1	...	− 9·0	− 8·2	Indirect comparison; line not so well seen as before.
30	M	1	4	2½	0	0·5	b_1	...	−10·8	− 8·2	Indirect comparison; line seen much better; wind not so high.
30	M	1	4	2½	0	1·2	b_1	...	− 7·1	− 5·8	Indirect comp.; lines seen very well.
June 1	M	1	3	2½	0	0·7	F	...	...	− 7·4	Indirect comparison.
1	M	1	2	2½	0	0·7	F	...	− 9·6	...	
1	M	1	2	2½	0	0·7	F	...	− 3·1	− 3·7	Indirect comparison.
1	M	1	1	2½	0	0·6	b_1	...	−13·7	−14·7	
								Mean	−12·5 ± 1·3	−11·3 ± 1·2	Calculated motion −8·2 miles per second.
							Probable error of 1 observation		5·1	4·5	
1876 Sept. 21	WC	1	...	2	27	5·8	F	...	+41·1	+40·7	Direct comparison with the spectrum of the sky.
21	WC	1	...	2	27	5·8	F	...	+23·1	...	Compared with the spectrum of the sky.
21	WC	1	...	2	27	5·8	F	...	+26·1	...	
21	WC	1	...	2	27	3·3	b_1	...	+34·2	+45·6	Direct comparison with the spectrum of the sky.

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							Venus—continued.				
Sept. 21	WC	1	...	2	27°	3·3 d	b_1	...	+24·3	...	
21	M	1	...	2	27	2·2	b_1	...	+15·1	...	Compared with the spectrum of the sky.
21	M	1	...	2	27	2·2	b_1	...	+15·5	...	
21	M	1	...	2	27	2·2	b_1	...	+18·4	...	
22	M	1	...	2	23	2·4	F	...	+31·3	...	Compared with the spectrum given by a vacuum tube.
22	M	1	...	2	23	2·4	F	...	+15·6	...	
22	M	1	...	2	23	2·4	F	...	+24·1	...	
22	M	1	...	2	23	2·4	F	...	+17·9	...	Compared with the spectrum of the sky.
							Mean		+23·9 ± 3·4	+43·2 ± 11·8	Calculated motion +8·0 miles per second.
							Probable error of 1 observation		11·9	16·6	
1876 Oct. 12	WC	1	4	2	26	3·0	b_1	...	+31·3	+28·7	Direct comparison with the spectrum of the sky.
12	WC	1	4	2	26	3·0	b_1	...	+35·3	+28·7	
12	WC	1	2	2	26	3·0	b_1	...	+10·7	...	Compared with the spectrum of the sky.
12	M	1	4	2	26	2·8	b_1	...	+ 9·6	+16·6	Direct comparison with the spectrum of the sky.
12	M	1	4	2	26	2·8	b_1	...	+ 8·1	+16·6	
12	M	1	4	2	26	2·8	b_1	...	+15·5	+16·6	
							Mean		+19·1 ± 4·9	+21·4 ± 7·4	Calculated motion +7·9 miles per second.
							Probable error of 1 observation		11·9	16·6	

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Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared.	Earth's Motion in Miles per Sec.	Concluded Motion of Star. Measured.	Concluded Motion of Star. Estimated.	Remarks.
							Venus—continued.				
					°	d					
Nov. 7	WC	1	3	4	30	3·3	b_1	...	+15·0	+ 7·6	Direct comparison with the spectrum of the sky.
7	WC	1	3	4	30	3·3	b_1	...	+13·5	+ 7·6	
7	WC	1	3	4	30	3·4	b_2	...	+11·8	+ 6·5	
7	WC	1	3	4	30	3·4	b_2	...	+11·2	+ 6·5	
7	M	1	4	4	30	3·8	b_1	...	+ 9·4	+ 8·4	
7	M	1	4	4	30	3·3	b_1	...	+12·9	+11·2	
7	M	1	2	4	30	3·7	F	...	+ 7·7	+ 6·5	
7	M	1	3	4	210	3·8	b_1	...	+ 4·4	+ 7·2	
7	M	1	3	4	210	3·8	b_1	...	+14·9	+16·8	
7	WC	1	2	4	210	7·0	b_1	...	+21·2	+10·4	
8	M	1	2	4	120	3·3	b_1	...	+17·7	+ 9·0	
8	M	1	1	4	120	2·2	b_1	...	+ 7·9	+ 4·8	
8	M	1	3	4	120	4·7	b_1	...	+11·8	+10·0	
8	M	1	1	4	300	3·6	b_1	...	− 0·7	+ 0·0	Indirect comparison.
8	M	1	2	4	300	3·7	b_1	...	+10·0	+12·4	Direct comparison with the spectrum of the sky.
8	M	1	3	4	300	3·7	b_1	...	+11·7	+12·4	
							Mean		+11·7 ± 1·1	+ 9·1 ± 0·6	Calculated Motion +7·3 miles per second.
							Probable error of 1 observation		4·5	2·4	

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An Endeavour to simplify the Method of making the Correction for the Spheroidal Figure of the Earth in Lunar Observations, and particularly with reference to its effect upon the "Lunar Distance." By F. C. Penrose, Esq.

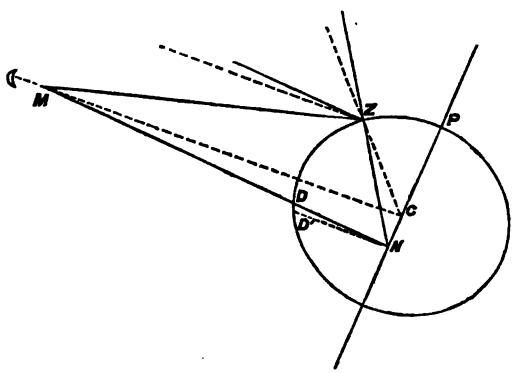
The correction for the Spheroidal Figure of the Earth is generally neglected in ordinary Lunar Observations. Nor is this to be wondered at, if the navigator is expected to follow the rules generally laid down for the purpose.

In endeavouring to simplify these rules, I lighted upon a plan which cleared up these difficulties to a very great degree; but, as it has been since pointed out to me, the discovery has been anticipated and its value already recognized.

This, however, does not, I think, preclude my bringing it before such members of the Society as are unaware of it, especially as it does not appear in the works mostly in use; and I indulge in the hope, with the help of a graphic process, to render the management of this correction so easy, that there can be no reason for its being any longer neglected.

The quantity involved is sometimes so large as to be out of all proportion greater than the smaller corrections which are often scrupulously attended to: such as great accuracy in interpolating between the arguments of parallax, or in allowance for barometer and thermometer under ordinary conditions.

[I am not advising the neglect of these corrections; but only that when time is an object, they may be followed up somewhat more roughly; so that the time saved in them may be used for the correction for the Spheroid.]



When the Moon is referred to the Earth's centre C by the polar distance (viz.: through PCM and the radius vector CM), for any point Z at any latitude, its parallax must be reckoned from the line ZC, which does not agree with the plumb-line—

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the standard of our measuring instruments—which intersects with the polar axis at some point N beyond the centre.

By referring the observation to the point N, the complication of having the astronomical zenith and the geocentric zenith to deal with, which troubles all azimuths except the meridian, is avoided.

This only requires that the value of CN for any latitude should be tabulated (call this value n), and that an allowance should be made to the declination given in the *Nautical Almanac*, $= n \cos D$; if D be Moon's declination (geocentric).

This correction is always to be subtracted from the polar distance. But inasmuch as in this reckoning, the radius measuring the Moon's horizontal parallax for the latitude in question is NZ, instead of CZ, the tabular HP will have to be varied accordingly.

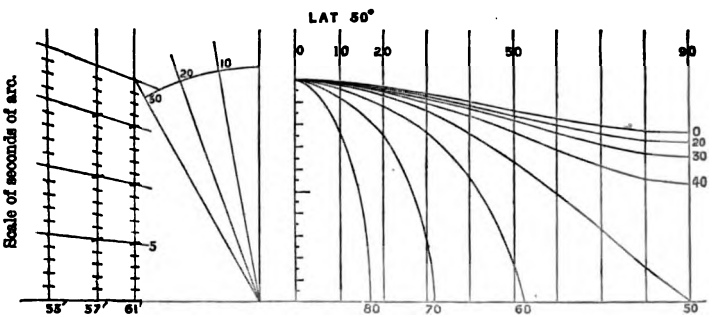
If, therefore, to the table above referred to are added the values of NZ, as well as those of n, the correction can be made by inspection.

These tables are given below.

If these corrections are first made in the original elements of computation of any lunar observation, the purpose is answered.

If, for instance, an altazimuth of ☽ has been observed, and these corrections be given to the elements of declination and parallax (there is no trouble with the azimuths), the Moon's hour-angle will at once be obtained.

But in many cases it may answer better to add this spheroidal effect as a correction afterwards, and for that purpose I have prepared a specimen-diagram adapted to latitude 50° (of course, North or South as the case may be).



Suppose the question to be the effect upon the altitude when in—

	°		
Latitude	50		
Declination	20	Parallax	57′
Altitude	40		

These give an hour-angle of about 51°.

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The ordinate in the diagram corresponding to these places shows 13″·4, but when reduced for declination by applying it to the slant line, it gives 12″·4, the answer required.

The hour-angles figured 0, 10, 20, 50, 90 repeat after 90°; for instance, the value corresponding to 130° is the same as that of 50°, etc.

Generally, the correction must be added to the altitude; but, if Moon's declination is greater than the latitude, the sign must be reversed, and it must be subtracted.

Probably the most important view of this correction is its bearing on the Lunar Distance.

This can be readily measured upon similar diagrams, if what has been called Latitude be taken for the star's altitude.

I have put together a case, which can be worked upon the diagram given:—

	°
Let the Latitude be	50
Moon's Declination	20
Apparent Altitude	30
Distance	30

These values require Moon's hour-angle about 66° 30′, and the azimuth-angle with respect to the star, 30°.

Treat the first on the diagram with hour-angle 66° 30′, altitude 30°. The ordinate on the chart gives 13″, but applied to the declination line, 12″·4.

Now consider the star's altitude as 50°, and the combined azimuth 30°.

The ordinate reads ·76 on the division under hour-line 0.

Then	12·4	
	·76	
	7··	
	87·	
	94	*Answer.* 9″·4.

There are cases where 9″·4 in a lunar distance would influence the longitude by 45°, and often this amount of 9″·4 would be much exceeded.

Similar diagrams can also be used for many other purposes: as for instance, approximately giving the corresponding azimuth to a given altitude and hour-angle and declination.

They may also be used to form the entire operation of clearing the distance, instead of the small correction only above given, with a fair amount of accuracy.

Clearing the distance by means of the diagram in the example above given, HP being 57′, parallax in altitude affected by refraction = 50′ 56″. This worked out fully gives 49′ 38″ for

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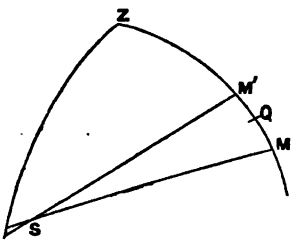
its effect upon the distance. Using the decimal fraction previously found upon 50′ 56″, we obtain 49′ 28″.

And even where exactness is required, an approximation easily obtained will enable the work to be shortened, in this manner, viz.:

Let Z be the Zenith; M the Moon's apparent altitude; MM′ the Parallax in altitude $= p$.



If MM′ were very small, the effect would be simply $= p \cos M = \frac{dz}{ds}$.

This will not, in ordinary cases, be sensibly incorrect if the point Q half-way between M and M′ be taken, and a proper allowance be made for the alteration of SM. The altitude of Q comes at once by applying $\frac{p}{z}$; and the corresponding value of SQ results from the approximation referred to derived from the diagram.

In estimating these corrections, whether of the whole effect known as clearing the distance, or only the part resulting from the spheroidal figure, which is the particular object of this discussion, it is of course of primary importance to know whether it should be estimated + or −.

This will always depend upon the angle at the Moon; calling this M, when M is greater than 90°, the distance will be increased, when less, diminished. When the star's altitude is greater than that of the Moon, the angle at M is always acute. Also, when the distance SM is greater than the star's co-altitude, M is always acute.

Rule for doubtful cases:—M will be acute or obtuse, according as cos b is greater or less than cos z cos s.

1876, *Nov.* 10.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. DECEMBER 8, 1876. No. 2.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Capt. James Waterhouse, Surveyor General's Office, Calcutta,

was balloted for and duly elected a Fellow of the Society.

Note on Prof. Langley's Paper on the Direct Effect of Sun-spots on Terrestrial Climates. By W. Mattieu Williams, Esq.

Prof. Langley determines quantitatively the effects respectively produced by the radiations from the solar spots, penumbra, and photosphere upon the face of a thermopile, and infers that these effects measure their relative influence on terrestrial climate.

In thus assuming that the heat communicated to the thermopile measures the solar contribution to terrestrial climate, Prof. Langley omits an important factor, viz. the amount of heat absorbed in traversing the Earth's atmosphere; and in measuring the relative efficiency of the spots, penumbra, and photosphere, he has not taken into account the variations of diathermancy of the intervening atmospheric matter, which are due to the variations in the source of heat.

Speaking generally, it may be affirmed that the radiations of obscure heat are more largely absorbed by the gases and vapours of our atmosphere than those of luminous heat, and the great differences in the mere luminosity of the spots, penumbra, and photosphere justify the assumption that the radiations of a sun-spot will (to use the expressive simile of Tyndall) lose far more by atmospheric sifting than will those from the photosphere.

But the spot areas will be none the less effective on terrestrial climate on that account. A given amount of heat arrested by the Earth's atmosphere will have even greater climatic efficiency than if received upon its solid surface, inasmuch as the gases are worse radiators than the rocks, and will therefore, *cæteris paribus*, retain a larger proportion of the heat they receive.

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I have long ago endeavoured to show * that the depth of the photosphere, from the solar surface inwards, is limited by dissociation; that the materials of the Sun within the photosphere exist in a dissociated, elementary condition; that at the photosphere they are, for the most part, combined. This view has since been adopted by many eminent solar physicists, and if correct, demands a much higher temperature within the depths revealed by that withdrawal of the photospheric veil which constitutes a sun-spot.

If I am right in this, and also in supposing the spot-radiations to be so much more abundantly absorbed than those of the photosphere, that in spite of the higher temperature of the spots, the *surface* of the earth receives from them the lower degree of heat measured by Prof. Langley, another interesting consequence must follow. The excess of spot-heat directly absorbed by the atmosphere, and mainly by the water dissolved or suspended in its upper regions, must be especially effective in dissipating clouds and checking or modifying their formation. The meteorological results of this may be important, and are worthy of careful study.

In thus venturing to question some of Prof. Langley's inferences I am far from underrating the interest and importance of his researches. On the contrary, I regard the quantitative results he has obtained as especially valuable and opportune, in affording means of testing the above-named and other speculations in solar physics. Similar observations repeated at different elevations would decide, so far as the lower regions of our atmosphere are concerned, whether or not there is any difference in the quantity of heat imparted by the bright and obscure portions of the Sun to our atmosphere. If the differences already observed by Prof. Langley vary in ascending, a new means will be afforded of studying the constitution of the interior of the Sun and its relations to the photosphere. Direct evidence of selective absorption by our atmosphere may thus be obtained, which would go far towards solving one of the crucial solar problems, viz. whether the darker regions are hotter or cooler than the photosphere.

The obscure radiations from the Moon must be absorbed by our atmosphere like those from the sun-spot, and may be sufficently effective to account for the alleged dissipation of clouds by the full moon.

In both cases the climatic influence is greatly heightened by the fact, that all the heat thus absorbed is directly effective in raising the temperature of the air. The action of the absorbed heat in reference to cloud-formation is directly opposite to that of the transmitted solar heat, which by evaporation of surface water supplies additional cloud material, instead of effecting its dissolution.

* *The Fuel of the Sun*, chapters 4 to 10.

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Spectroscopic Results for the Rotation of Jupiter and of the Sun, obtained at the Royal Observatory, Greenwich.

(*Communicated by the Astronomer Royal*).

(*Continued from p. 36 of the 'Monthly Notices' for November 1876. For the explanation of these observations see pp. 23 and 24 of the above No.*)

Rotation of Jupiter.

Relative motion of East and West limbs in the line of sight deduced from the relative displacement of the F-line.
The slit was tangential to the limb.

Date.	Observer.	No. of Measures.	Weight.	No. of Prisms.	Position-Circle.	Width of Slit.	Line compared	Earth's Motion in Miles per Sec.	Concluded Motion. Measured.	Concluded Motion. Estimated.	Remarks.
					°	d					
1876 June 26	M	1	½	2½	16½	0·5	F	...	+40·5	...	Line very faint; the slit about 0″·6 from the planet's limb.
26	M	1	½	2½	16½	0 7	F	...	+11·9	...	The slit about 0″·4 from the planet's limb.
26	M	1	2	2½	16½	1·7	F	...	+30·4	...	Line much better seen, but still very faint.
								Mean	+29·0		Calculated relative motion +32 miles per second.

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Rotation of the Sun.

Dispersion—Ten Compound Prisms; Magnifying Power 36.

1 rev. of Micrometer = 3·3 tenth-mètres, corresponding to 103 miles per second at D
= 2·0 „ „ 72 „ „ *b*

The readings increase towards the blue.

1876, May 30d 4h Observer—Mr. Christie.

Measures of the line 5161·5 (Ångström) near b_4

Micrometer Readings.

Position-Circle 270°. E. Limb. r	W. Limb. r	Displacement. E. Limb—W. Limb. r
(1) ·379		
	(2) ·335	+0·044
(3) ·374		
	(4) ·346	+0·028
(5) ·372		
	(6) ·362	+0·010
(8) ·400	(7) ·366	+0·034
(10) ·402	(9) ·363	+0·039
(12) ·372	(11) ·342	+0·030
(14) ·378	(13) ·358	+0·040

Mean displacement, E. limb—W. limb +0·032
corresponding to +2·30 miles per second

Position-Circle 0°. S. Limb. r	N. Limb. r	S. Limb—N. Limb. r
(1) ·634	(2) ·649	−0·015
(3) ·645	(4) ·635	+0·010
(5) ·610	(6) ·613	−0·003
(7) ·628	(8) ·621	+0·007
(9) ·646	(10) ·639	+0·007

Mean displacement, S. limb—N. limb +0·001
corresponding to +0·07 mile per second

Probable error of 1 measure of displacement = 0r·010 or 0·7 mile per second

Concluded Motion in miles per second.

	Position-Circle.	Line	No. of Obs.	E. Limb—W. Limb. Observed.	Calculated.
1876 May 29	90°	D_1	20	+2·26 ± 0·16	+2·35
30	270	D_1	7	+2·26 ± 0·27	
30	270	near b_4	7	+2·30 ± 0·27	
				S. Limb—N. Limb.	
30	0	D_1	6	+0·02 ± 0·29	
30	0	near b_4	5	+0·07 ± 0·31	

The part of the spectrum observed was in each case at a distance of about 8″ from the limb.

The position-angle of the Sun's N. Pole was 344½°.

The period of rotation has been taken as 25⅓ days.

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On the Error of the Tabular Place of Venus on December 8, 1874.

By Colonel J. F. Tennant, R.E., F.R.S.

(*From a Letter to E. Dunkin, Esq., F.R.S.*)

After coming here last January I compared the tabular places which I got for the transit of *Venus* by the Astronomer Royal's tables with those I had used. I found that the printed tables were 2″·03 in excess of mine in the R.A. of the Sun. I was anxious to find the source of this before saying anything about it, but many interruptions have occurred. All I can say is, that making a third computation in the same way that Captain Campbell and I had deduced all the formulæ, I got results only numerically different in the last place from those I had got before. It is, nevertheless, a fact that the Tables published at Greenwich are right; but it is curious that Captain Campbell and I, using an arithmometer in computations, should have entirely agreed, and that a third calculation with a different instrument gave the same result, all *three being wrong*.

Now to the effects. In the *Monthly Notices* of November 1875, you gave errors of the place of *Venus*. These are affected in R.A., and I have already sent you a correction to the difference in N.P.D. With the new correction they should stand :—

Correction to (R.A. ♀) −(R.A. ⊙) = +6″·50−0″·071 dL−0·989 $d\pi$,

„ (N.P.D. ♀)−(N.P.D. ⊙) = −2″·24−0″·017 dL−2·689 $d\pi$.

Calcutta,
1876, *November* 3.

On some Phenomena of the Internal Contacts common to the Transits of Venus, observed in 1769 *and* 1874, *and some Remarks thereon.*

By E. J. Stone, M.A., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

When the Observations of the Transit of *Venus*, 1874, are published in detail, I hope to examine the observations of the internal contacts with reference to their bearing on our determinations of the Sun's distance. I should have preferred not to have written upon the subject before the whole of the materials collected were available. But an impression has been slowly hardened into a conviction that none of the skilled observers, who, in 1874, observed the internal contacts with good instruments, saw the so-called black-drop phenomenon. Such an impression is, I am quite sure, unfounded, and it is perhaps desirable that this should be pointed out. The essential facts

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are in this case, as in too many other cases of the kind, becoming veiled in a mist of words.

Undoubtedly, if we are prepared to assume, on *à priori* grounds, that what a good observer, provided with a good instrument, should see, is the simple geometrical contact at a point, and that any observer who has seen more, must be either an unskilled observer, or have been provided with a defective instrument, we shall find no difficulty in establishing, to our own satisfaction, the conclusion which I have mentioned. But, on the other hand, there will be no difficulty in showing that observers have seen the "black-drop," who would have been considered observers of skill, and to have been provided with good instruments, had their observations not failed to satisfy some preconceived ideas of the nature of the phenomena which should be presented at the internal contacts. And here, perhaps, I may be permitted to add a word or two in the way of a caution. Nothing whatever depends upon the phrase "black-drop" or "black-drop phenomenon." This is merely the way in which one observer, in 1769, thought proper to describe the lingering nature of the contact, which is the cause of the only systematic error to be feared in a discussion of durations derived from internal contacts, and the cause of the principal systematic error in a general discussion of contact observations.

Whether the observer prefers to speak of the disturbance of the apparent limb of the Sun near the point of contact, as an "ombre," a "black-drop," a "ligament," a "thread," or merely to assert generally, that "the contact was gradually established," is a point of very little importance.

The important point connected with these protracted contacts is the sensible time over which the contact extends; this renders no longer admissible the assumption that all contacts take place with the same angular separation of the centres of *Venus* and the Sun. For if, at ingress for example, after the geometrical contact appeared to be established there still continued for thirty or more seconds some disturbance of the Sun's apparent limb, near the point of contact; the time at which the observer saw the geometrical contact, and the time at which he last saw any disturbance of the Sun's limb near the point of contact, cannot be combined together in any mathematical investigation without allowing for the relative change in the positions of *Venus* and the Sun in the thirty or more seconds which elapsed between the observations, or without accepting residual errors of fifteen or more seconds. And when we have to combine observations of contacts made by different observers, we cannot proceed a single step without an assumption. We have to assume that contacts of apparently the same class take place at all the different stations with the same angular separations of the centres. Unless this assumption is approximately true for some class of contacts, attempts to determine a value of the solar parallax from contact observations in a transit of *Venus* must entirely fail. It is, how-

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ever, a pure assumption, which may or may not turn out to be correct. Like other assumptions of the class, it can only be proved or disproved by logically tracing its consequences, and comparing them with the known facts, which are the observations made at the different stations.

But suppose, as will be found to be the case, that some of the observers, who have seen the contact of a lingering or protracted character, have preferred to give as the time of contact the times when they saw the so-called geometrical contact, whilst others have preferred to give the times at which at ingress they last saw, or at egress first saw, any disturbance of the Sun's apparent limb near the point of contact. How are these incongruous observations to be combined? It is clearly useless to attempt to combine them under a single assumption, that all the contacts took place at the same angular separation of the centres of the planets, unless we are prepared to admit, in the comparison of our theory with the observations, residual errors, or so-called errors of observation, at least equal to one-half the time over which the contacts have been observed to be prolonged. Enough is already known of the observations made in 1874 to justify the statement that these contact observations thus treated cannot lead to any accurate value of the solar parallax without the adoption of some method of selection of materials equivalent to the rejection of a considerable number of observations. If we were sufficiently acquainted with the causes which produce the appearances of prolonged contact, and were in possession of the requisite data upon which to base the necessary calculations, our proper course, to utilise the whole of the contacts, would be to adopt as our standard phase the *real contact*, an expression which in the case supposed would have a clear, distinct, and definite meaning, and to apply corrections to the times of the observed contacts to reduce them to the corresponding times of real contact. But an error of a tenth of a second of arc in assumed difference of semi-diameter is equivalent to an error of three seconds in time in the observed contact. I am afraid that we possess neither the theoretical knowledge nor the requisite data to render such a method available within allowable limits of error. If such be the case, we are thrown back upon the method which I adopted in my paper on the "Rediscussion of the Transit of *Venus*, 1769." Just as we assume that all the observations of geometrical or apparent contact are seen at some definite angular separation of the centres of the planets, so must we assume that all the observations of the first and last disturbance of the Sun's limb near the point of contact take place at a definite angular separation of the centres. The second assumption is as legitimate as the first; its approximate truth can only be proved or disproved in the same way, by logically tracing the consequences of the assumption and comparing them with the observations. In practice we must expect to find both of these assumptions satisfied with greater or less accuracy, according as

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greater or less uniformity has been secured in the instrumental equipment of the observers, the brightness of the field of view in which the observations were made, and in points to which the attention of observers was specially directed.

In the transit of 1769 there were ten complete observations of duration from internal contacts. The smallness of the residual errors in my rediscussion of these observations proves that, so far as they are concerned, the assumptions to which I have called attention were at least very approximately satisfied. Whether such will be the case with the contact observations of 1874 remains to be seen. The similarity of the phenomena of the contacts observed in 1769 and 1874, to which I shall call attention, may probably have some effect in reassuring astronomers of the objective character of the phenomena, and may thus render more general the acceptance, as at least *à priori* probable, which is all that is required, of the assumptions which I have already mentioned and of the other supplementary assumptions of the same class, which the want of uniformity in instrumental equipment and attempts to introduce subsidiary phases, which appears to have been made in 1874, may be found to have rendered necessary.

I have entered into these details because they must be understood before the importance of the remarks made by the observers can be appreciated, and because the principle upon which my "Rediscussion of the Transit of *Venus*, 1769," is based has been entirely misunderstood by one popular writer on the subject.

In the present paper I shall make no further reference to my own observations than to say, that I saw the so-called penumbra of Cook and Green. The light of the penumbra was, however, so faint in comparison with the direct light of the Sun that, when attention was concentrated on the contact all distinction between the central darker portions of the planet were lost sight of. The disturbance of the Sun's limb at egress appeared to me to commence some considerable time before the apparent contact, when, in fact, the limb of *Venus* was more than the second of arc from the apparent limb of the Sun. At first, however, the disturbance was of a very slight character. The appearance at first presented was something like that of a hair in vibration before the eyes. Such an appearance I consider as an indication that some of the pencils of light which had previously reached the eye from the Sun's disk were more or less interrupted by the planet *Venus* or its atmosphere. The appearance of disturbances soon assumed a definite character; and I should be content to describe the connection between the limbs of *Venus* and the Sun as a ligament. The apparent contact was rendered more difficult than would otherwise have been the case by the appearance of this ligament, or, in other words, by the disappearance of a sensible portion of the Sun's limb near the point of contact. The observations of Contact were made in a rather bright field of view.

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The definition was good, the sky perfectly free from clouds, and there was but little wind.

I am aware that it has been stated that my observations have been affected by my theoretical views; and, as the same charge might probably be brought against some other observations to which I could appeal, I shall, for my present purpose, confine myself to observations made by the French observers. The instrumental equipment of these observers was supposed, before the transit, to be sufficiently perfect to prevent any instrumental defects affecting their observations. It is clear, also, that the observers, if biassed at all, were not biassed in favour of any views of mine, and their observations have been printed in some detail, and are available for general examination. The observations to which I shall first appeal to prove that the phenomenon of the black-drop did present itself in the transit of 1874 are those made by M. Janssen at Nagasaki. M. Janssen, in describing the contact at ingress in the *Annuaire*, 1876, says that "le premier contact est obtenu par M. Tisserand et par moi. Dans l'equatorial de 8 pouces, dont la lunette est très-bonne, l'image de *Vénus* se montre très-ronde, bien terminée, et la marche relative du disque de la planète, par rapport au disque solaire, s'exécuta géométriquement sans aucune apparence de ligament ni de goutte." Nothing can apparently be clearer than the statement of M. Janssen; and it has therefore been seized upon as conclusive evidence against the black-drop in 1874. But M. Janssen continues his account of his observations as follows:—"Mais il s'ecoula un temps assez long entre le moment où le disque de *Vénus* paraissait tangent intérieurement au disque du Soleil et celui de l'apparition du filet lumineux." This prolongation of the disturbance of the Sun's limb near the point of contact after the geometrical contact, for a "temps assez long" constitutes what other observers have called, and I should call, the black-drop. M. Janssen has apparently confined himself to giving the time at which he saw the geometrical contact; but he might, had he pleased, have given us instead the time later by the "temps assez long" which corresponded to the first appearance of the "filet lumineux." To show that this is really the point upon which controversy has hinged, I will give, for comparison with Janssen's Observations, those made by Wales and Dymond in 1769.

These observers state, "We took for the instant of last internal contact the time when the least visible thread of light appeared behind the subsequent limb of *Venus*; but before that time *Venus's* limb seemed within that of the Sun." It is clear, therefore, that Wales and Dymond in 1769 and Janssen in 1874 saw similar phenomena; but that Wales and Dymond preferred to give the time corresponding to the last appearance of any disturbance, or to the first appearance of the "filet lumineux"; whilst Janssen preferred to give the time corresponding to the geometrical contact. In the *Annuaire* for 1876—where are also

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some very important remarks by M. Janssen which appear to prove, in the most conclusive manner, the objective character of the phenomenon—M. Janssen mentions that, after the geometrical contact, he proceeded to take photographs, and that these photographs showed that the connection between the limbs of *Venus* and the Sun had not ceased.

At the egress, M. Janssen's observations would appear to have been picked up through clouds, and the details are wanting.

The evidence thus afforded by M. Janssen of the existence of the black-drop in 1874 is not only of the most conclusive character, but it is above any suspicion of being the result of preconceived ideas. It would appear that the observer had some misconception of the real character of the black-drop, and his evidence in favour of its existence is given quite unconsciously. The important fact mentioned by M. Janssen, that after his observations of the geometrical contact the photographs still showed that the connection between the limbs had not ceased, proves that the prolonged contact is not a mere optical delusion, "for photographs have no nerves," to whatever other sources of error they may be liable. It may be remembered that soon after the transit great stress was laid upon the supposed fact that Capt. Abney had secured a photograph of the contact, and that there was no appearance of any black-drop. It was, however, found, on examination, that the contact had not even commenced at the time the photograph was taken; but the impression made by the original statement, although admitted to be erroneous, has never, I fear, been removed. The contradictions of such statements do not usually receive the same publicity, or attract the same attention, as the original statements.

The next observations to which I shall refer are those made by Capt. Mouchez at the Island of St. Paul. Capt. Mouchez's telescope had an aperture of eight French inches. The following account of these observations is taken from the *Annuaire*, 1876:

Speaking of the internal contact at ingress, Capt. Mouchez says:—"Les nuages devenaient de plus en plus rares, le ciel plus transparent, les images d'une très-grande netteté. Un quart d'heure environ après le premier contact, quand la moitié de la planète était encore hors du Soleil, j'aperçus subitement tout le disque entier de *Vénus* dessiné par une pâle auréole, plus brillante dans le voisinage du Soleil qu'au sommet de la planète. Pour bien constater que je n'étais pas le jouet d'une illusion, je pris immédiatement des mesures micrométriques du diamètre de *Vénus*, dans le sens de la ligne des centres et dans le sens perpendiculaire; bien que le premier de ces diamètres fût encore à moitié hors du Soleil, et limité extérieurement seulement par l'auréole, j'obtins, à 1 seconde près, exactement la même valeur: c'était donc bien le disque entier très-net de la planète que j'apercevais.

"Cette apparition, aussi rémarquable qu'inattendue, peut sans doute être attribuée en partie à l'atmosphère solaire rendue

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visible par contraste, en partie aussi par l'atmosphère de *Vénus*. Le ciel était devenu si pur à la suite de la tempête et l'auréole était si brillante, qu'on peut voir sur nos photographies des traces de ce curieux phénomène. Le deuxième contact fut observé dans de bonnes conditions vers $7^h\,30^m$; mais, au lieu de voir l'apparence de la goutte noire, qui a pour effet de tenir les deux cornes encore séparées après le contact, j'ai vu le phénomène tout contraire: l'arc lumineux de l'auréole réunissait ces deux cornes avant le contact. Nous nous trouvions évidemment dans des conditions exceptionnellement favorables sous le rapport de la pureté de l'atmosphère et de l'excellence de notre lunette."

It is to be regretted that Capt. Mouchez has not stated more clearly whether there was or was not any disturbance of the Sun's limb after the contact.

It should be noticed that the circumstances under which the auréole first presented itself to Capt. Mouchez are exactly similar to those under which it first appeared to Wales and Dymond in 1769.

These observers state, "Soon after *Venus* was half immerged, a bright crescent or rim of light encompassed all that part of the circumference which was off the Sun, thereby rendering her whole periphery visible. This continued very bright until within a few minutes of the internal contact, and then vanished away gradually." Upon these points see the observations of M. Heraud, which will be subsequently given. The observations of Capt. Mouchez are chiefly valuable, for my present purpose, for the light which they throw upon Cook and Green's observations in 1769. The auréole is nothing more than Cook and Green's penumbra. I shall have something more to say upon this point with respect to MM. Heraud and Bonifay's observations.

The following accounts of the observations of MM. Heraud and Bonifay at Saïgon are extracted from the *Comptes Rendus* (25 Janvier 1875):—

"*Observation de M. Heraud.*

"Objectif de 160 millimètres: grossissement, 155.

"*Entrée.*—A $21^h\,17^m$ la planète étant déjà entrée de plus de deux tiers, je remarque que la partie extérieure de son limbe est nettement indiquée par un filet lumineux pâle, qui, réuni aux franges de l'image intérieure, dessine un rond parfait. Ne m'attendant pas à ce phénomène, je ne puis noter l'instant précis de son apparition; l'heure ci-dessus est donnée à 1 minute près.

"L'échancrure s'arrondit de plus en plus, je suis le rapprochement régulier des pointes brillantes du croissant solaire; à un moment donné, ces pointes me paraissent immobiles. Je ne vois plus la petite auréole extérieure, la partie noire de l'échancrure me paraît absolument ronde et tangente à la ligne fictive qui fermerait le bord du Soleil. Je donne un top et, perdant de

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vue les franges, je crois un moment que le contact s'est produit et qu'il est perturbé par la goutte noire. Je regarde avec attention, et 20 secondes plus tard je note l'apparition entre l'image noire et le fond du ciel d'une lueur très-pâle teintée de noir en son milieu ; cette lueur, qui arrive comme un transition entre l'obscurité et la lumière, s'agrandit et s'anime, et, en même temps, la petite tache noire devient plus petite. Je la signale comme formant une sorte de pont obscur entre le bord des astres qu'elle laisse cependant distincts ; elle disparaît presque aussitôt, et le filet lumineux est dépouillé de tout trouble, les franges reprennent leur netteté autour de la planète. Les phénomènes de l'entrée sont accomplis. . . . .

" *Sortie.*—Les images sont moins calmes que dans la matinée, mais encore nettes ; l'image de la planète est toujours bien frangée.

" La planète se rapprochant de plus en plus, je suis attentivement le filet lumineux. Je signale successivement l'apparition d'un filet lumineux très-faible, puis celle d'un filet lumineux presque nul. Le filet très-pâle est teinté de noir comme dans la matinée, et ressemble à ce qu'il était lors de son apparition à l'entrée ; mais je n'ai pas revu le ligament plus net signalé dans la première observation. Toute apparence lumineuse disparaît ; c'est *l'instant du contact* ; la partie noire de l'image de *Vénus* est à une distance appréciable du bord du Soleil ; peu d'instants après, cette distance me paraît nulle, et l'échancrure noire semble tangente au bord du Soleil ; les cornes du croissant s'éloignent, mais sans prendre tout de suite l'acuïté qui correspond à une intersection géométrique ; je les signale comme étant un peu émoussées, et ce n'est que trente-trois secondes plus tard que l'échancrure me paraît bien nette.

" *Observation de M. Bonifay.*

" La lunette dont je me suis servi est de la maison Secrétan ; elle a un objectif de 55 millimètres d'ouverture et un grossissement de 63.

" La mise au point sur les étoiles et sur les taches du Soleil s'opérait sans difficulté et donnait des images très-nettes. C'est cette mise au point qui été adoptée pour l'observation.

" J'ai pu après l'observation, déterminer, avec la lunette méridienne prise comme collimateur, la mise au point sur le plan focal. Elle exigeait que le tube de l'oculaire fût légèrement moins enfoncé que la mise au point sur le cercle maximum d'aberration.

" L'observation a été faite dans le Jardin de l'Observatoire, avec cette lunette, montée en altazimut, sur une table massive, à 20 mètres à l'est de l'Observatoire.

" *Entrée.*—Quand la planète se projette sur le Soleil, je constate que l'image est noire, de teinte parfaitement uniforme et à contours très-nets ; elle conserve ce même aspect pendant toute l'observation.

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"A 21^h 18^m, temps moyen de Saïgon, le contour de *Vénus* extérieur au disque solaire s'illumine légèrement, à commencer par le bas de l'image, qui reste constamment plus visible que le haut. La circonférence planétaire paraît ainsi complétée d'une manière très-visible sur le ciel par cet arc lumineux qui semble la continuer exactement.

"Cet effet subsiste quand la planète avance; peu à peu le disque solaire, entre les bords voisins des deux astres, devient de plus en plus obscur à côté du futur point de contact. Quand le moment du contact approche, on ne distingue plus le bord du Soleil qui jusqu'alors se prolongeait nettement jusqu'au disque planétaire; les deux cornes de l'echancrure sont séparées de *Vénus* par un intervalle obscur; mais je continue à voir le bord de la planète, qui reste légèrement lumineuse. Cette circonférence lumineuse me paraît tangente au bord du Soleil, prolongé par la pensée dans l'ombre; c'est le moment qui me semble être celui du contact. La planète s'éloigne du bord du Soleil, laissant obscur l'intervalle qui les sépare; un filet lumineux vient compléter la circonférence du Soleil en réunissant les deux cornes de l'echancrure: l'ombre qui persiste entre *Vénus* et le Soleil n'est complètement dissipée que vingt-trois secondes plus tard. . . . .

"*Sortie*.—Les images sont ondulantes; néanmoins comme le matin, les contours de la planète sont bien tranchés; sa teinte est uniformément noire. Quand *Vénus* s'approche du Soleil, une ombre s'étend entre les deux astres; le bord du Soleil se rompt en deux cornes au point où doit s'effectuer le sortie, et les contours de deux astres en ce point deviennent invisibles. Je ne puis juger du moment du contact qu'en l'appréciant de mon mieux, en continuant par la pensée les parties invisibles des circonférences; de même dans une observation au sextant d'une hauteur de Soleil, si le bout de l'astre est en partie masqué par un petit nuage, il arrive qu'on cherche à obtenir le contact au juger.

"Quand la planète commence à émerger j'examine si sa circonférence devient lumineuse, comme le matin: le phénomène ne paraît pas se reproduire. L'échancrure diminue de plus en plus; peu à peu les ondulations du Soleil rendent son observation difficile, elle devient enfin invisible. . . . ."

In these observations we have all the phenomena observed in 1769 by Wales, Dymond, Hell, Chappe, Cook, and Green, reproduced with modern instruments, and in the eyes of observers who were certainly not biassed in favour of any views of mine. The fringe is here again the penumbra of Cook and Green. It may, perhaps, be remembered that Cook and Green, in 1769, observed the geometrical contacts of a penumbra as dark, or nearly as dark, as that of the planet, and also the geometrical "contacts of the dark body of *Venus*." The following remarks of M. Herand are important as bearing on these points, and on the gradual establishment of the contact:

"L'apparition du filet lumineux a été pour ainsi dire graduelle; de plus, comme je l'ai dit dans le procès-verbal, la sépa-

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ration de l'image noire et des franges était plus nette, aussi nette au moins que la séparation des franges et l'image lumineuse du Soleil, et j'ai eu quelque peine à me défendre de considérer comme le bord de *Vénus* la limite de l'image noire, d'autant plus que ces franges n'ont reparu que très-lentement au point où le contact s'était fait: et c'est ainsi que j'avais noté d'abord à l'entrée le moment où la partie noire de l'echancrure me paraissait ronde et tangent au Soleil."

It will be seen, therefore, that Mons. Heraud had some difficulty in refraining from making an observation of the contact with the so-called "dark body of *Vénus*," like that made by Cook and Green in 1769, in addition to the geometrical contact of the outer boundary of *Vénus*. M. Heraud also remarks, "Pour M. Bonifay, l'arc lumineux a persisté jusqu'au moment du contact et peut-être jusqu'a près ce moment, tandis que pour moi il avait disparu: je dois dire que, preoccupé de l'observation du contact, j'avais un peu perdu de vue la petite auréole, et je n'ai pas noté l'instant de sa disparition." M. Heraud's remarks on this point agree with those made by Wales and Dymond; and I should be prepared to accept them as representing fairly my own observations.

*In discussions of Cook's and Green's observations before the appearance of my paper, the geometrical contacts of the penumbra as dark, or nearly as dark, as the planet, were taken as "real contacts" "the first or last appearances of any disturbance at the Sun's limb near the point of contact," or "the first or last appearance of the least visible thread of light." The contacts with the "dark body of *Venus*" were taken as the apparent contacts. These interpretations appeared to me as unsatisfactory. If the penumbra was as dark, or nearly as dark, as the planet, the observers who observed geometrical contacts without discovering any distinction between the penumbra, or fringe, and the central darker portions of the planet, must have observed also contacts with the penumbra. In this case Cook's geometrical contacts of the penumbra, instead of being real contacts, were apparent or geometrical contacts.

A reference to the drawings, of which copies are given in my papers, will show that at the time of the geometrical contacts with the "dark body of *Venus*," the disturbance of the Sun's limb extended over nearly a diameter of *Venus*, and that the true geometrical contact could not be thus intended. But the point which, as much as any other, influenced me, in the interpretation put upon these observations, was the remark made by Cook, that "the contacts were made gradually, and the time noted was when the thread of light was wholly broke by the penumbra." This showed that Cook and Green had seen the disturbances of the Sun's limb, before at egress, and, after at ingress, the penumbral contacts. It was clear, therefore, that Cook and Green's

* This sentence is printed according to the MS., but some correction is perhaps required.—[Ed.]

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contacts could not be real contacts in the same sense as those made by Wales and Dymond were. The confirmation of my views, on the interpretation to be put on Cook's and Green's observations, afforded by the observations of the French observers in 1874, is remarkable.

Since the appearance of my paper I am not aware that any astronomer has seriously maintained the correctness of the interpretations which had previously been held with respect to the nature of the contacts observed by Cook and Green. One astronomer doubted the goodness of the observations, and was inclined to attribute the appearance of the penumbra to instrumental defects. The observations of the French observers appear to show that there is no longer any ground for such a suspicion, and that the observations of 1769 are as good, or very nearly indeed as good, as the corresponding observations of 1874. Any one who will take the trouble to study my papers in the *Monthly Notices* for 1868, October, will see that the interpretation which I put upon the observations of Cook and Green is the most important point in my work. In fact, the only other step of any importance was the rectification of a similar mistake in Hell's observations, indicated by the fact that different interpretations had been assigned to the word "contactus," at the ingress and egress.

Small and unimportant changes are easily enough made in all such work. But when any astronomer will prove that one or more of the twenty internal contacts included in the ten complete durations observed in 1769 has been erroneously interpreted by me, and will show that when my erroneous interpretation is removed and the correct interpretation carried into the equations of condition, the ten durations are fairly represented, and that the value of the solar parallax deduced from the equations is no longer my value $8''{\cdot}91$, or one differing from it by $\pm\ 0''{\cdot}07$, but is Encke's value $8''{\cdot}58$, or one differing from it by $\pm\ 0''{\cdot}07$—then I shall be quite prepared to admit that my work has been without value. Before this is done I can only meet general statements that the work is not accepted, by asking those who assert that such is the case to go one step further and prove that it ought not to be accepted. If the work is inaccurate, the proof should be easy; but no proof of the kind has yet been given.

Royal Observatory, Cape of Good Hope,
1876, *November* 6.

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On some Diffraction Experiments of M. Ch. André with reference to Astronomical Instruments, and the General Theory of this Diffraction. By the Rev. S. J. Perry.

My attention was first called to these experiments during a visit I paid this year to France; and whilst in Paris I had the pleasure of observing with the instruments, and of noting the extreme care with which the experiments are being made under the most favourable circumstances. Some of the experiments are confirmatory of results already noted by other astronomers, as by Sir W. and Sir J. Herschel and the Rev. W. Dawes, whilst others, as well as the complete theory of the subject, are, as far as I am aware, due entirely to the labours of M. André.

The image of a luminous point in the focus of a telescope is known to be a central disk surrounded by bright rings, the diameter of the disk varying inversely as the aperture of the object-glass or mirror employed. Hence the limitation to the separating power of a given instrument. If, however, the centre of the field is covered, the diameter of the focal disk diminishes as the diaphragm is increased. The separating power is thus augmented, but the ratio of the intensity of the bright rings to that of the central disk is proportionately increased.

If we draw a curve, whose ordinates represent the intensity of the light of each point of the image, and whose abscissas are the angular distances of these points from the axis of the telescope, this intensity curve, drawn for any particular aperture, will hold good for any other aperture, provided the unit for the abscissas is made inversely proportional to the aperture. A revolution of this intensity curve round its vertical axis will form what M. André calls the Solid of Diffraction; and if the axis of this solid coincides with that of the telescope, the quantity of light on any element of the focal plane is proportional to the cylindrical portion of the volume of the solid of diffraction, the base of the right cylinder being the given element.*

When the object is of finite dimensions, instead of being a luminous point, there is no interference of the rays from the different points, but the intensity of the light at any part of the image is the sum of the intensities of the separate elements. Hence we obtain the following theorem:—If the solid of diffraction, corresponding to the aperture employed, be placed so that its axis, which is perpendicular to the focal plane, passes through a point (m), the cylindrical portion of the solid, comprised within the geometrical image of the object, measures the intensity of (m).

Applying this theorem to objects of different dimensions, we find that the intensity of the image of a brilliant straight line is measured by the surface of a section of the diffraction solid;

* The width of the solid of diffraction varies inversely as the aperture of the telescope.

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and that if the straight line is widened into a band, the measure of the intensity of the image is the volume of the same solid comprised between two sections, which widen out in the same proportion as the luminous band. Taking the more practical case of an object whose diameter is so considerable in every direction that we may consider the boundary lines as straight, we easily see that the focal image consists of two parts:

One similar to its geometrical image, depending on its form and apparent dimensions, but increasing with the aperture; the intensity being constant and maximum throughout:

The other overlapping and surrounding the first, its shape varying with that of the object, but its angular dimensions depending solely on the aperture. The intensity of this portion of the focal image, decreasing progressively, is reduced to one half at the limits of the geometrical image, and then quickly becomes insensible.

To find the intensity at the different points of this zone of diffracted light, which surrounds the geometrical image of any object of sufficient apparent magnitude, we must calculate the successive portions of the volume of the solid of diffraction intersected by a plane, which keeps parallel to the axis of the solid, whilst it moves from one edge of the zone to the other. As the extent of the zone of diffracted light bears a constant ratio to the maximum intensity of the focal image, the diameter of any body of sufficient brilliancy, observed on the same background, varies with the aperture. Thus for a 4-in. aperture the angular measure of the zone of diffracted light is 1″·4, on the supposition that light, reduced to $\frac{1}{30}$th of the central portion, ceases to affect the retina sensibly. Diameters are thus increased 2″·8 by a 4-in. telescope. This correction, called the Constant of Instrumental Diffraction, differs from the separating power of the telescope, and varies with the aperture of the telescope and the brilliancy of the object.

In order to verify experimentally these theoretical results, a hole was made in a piece of silvered copper, and a strong light from a Drummond lamp thrown upon it. Observing this by direct and reflected light, differences of 5″·82, 8″·87, and 13″·60, were found with apertures of 6·5, 2·9, and 1·7 centimeters.

A more accurate verification was made with a piece of blackened brass, in which two rectangular apertures had been carefully cut with bevelled edges, 3 centimeters in height by 1·5 in breath, and 1·5 apart. Direct light was alone used, and with apertures of 6·5, 3·0, and 1·7 centimeters, the exterior diameters were found to be 121″·15, 122″·17, and 125″·86, and the interior ones only 36″·13, 34″·48, and 31″·46, respectively.

Measures of the diameters of *Mercury* and *Venus*, whilst the planets were crossing the solar disk, also lead to the same conclusions.

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Thus, in the Transit of—

		Observer.	Instrument.	Aperture.	Diameter measured.	Reduced to Unity of Dist.
Mercury	4, 5 May 1832	Bessel	Heliometer	0·160	11·987	6·697
		Gambart	Equatoreal	0·070	9·290	5·184
„	8 May 1845	Mitchel	„	0·265	11·580	6·522
„	„	Mädler	„	0·224	11·754	6·542
„	„	Schmidt	„	0·068	10·853	6·057
„	8, 9 Nov. 1848	Arago	„	0·162	10·155	
„	„	Dawes	„	0·102	9·389	
„	„	„	„	0·072	9·369	
„	4 Nov. 1868	Wolf	„	0·204	9·430	6·367
„	„	Plummer	„	0·165	9·001	6·077
„	„	Struve	„	0·064	6·840	4·618
Venus	8 Dec. 1874	Mouchez	„	0·217	64·992	16·992
„	„	Tennant	„	0·152	63·948	16·904

Calculating the constant of instrumental diffraction for a 4-in. telescope from the last observations of *Mercury* and *Venus*, we obtain a mean value of 2″·634, which agrees closely with the theoretical value of 2″·80. If we compare the above diameters with measures taken at other times, we find that the diameter invariably decreases with the brilliancy of the background.

The corrections applied to the lunar diameter, when reduced from occultations of stars by the Moon, observed at the Royal Observatory with the East Equatoreal, affords another confirmation of the correctness of the preceding conclusions. The correction adopted for stars observed at the dark limb is −2″·54, and at the bright limb −0″·80; the difference is, therefore, 1″·74, whilst theory would give for the same instrument 1″·55.

When we increase the separating power of a lens by means of a central diaphragm, the constant of instrumental diffraction is increased, on account of a change in the form of the solid of diffraction, consisting in an increase of the relative volume of the parts external to the first minimum of intensity. If the aperture is thus reduced to $\frac{1}{2}$, the decrease of light ceases to be continuous, and the constant of instrumental diffraction increases for a 4-in. telescope from 2″·8 to 4″·0. This has been verified by observations of the Moon and also of artificial objects.

As the mathematical theory of the subject has been worked out fully in a published essay, it would be out of place to enter into the question here, especially as this short notice of the investigations of M. André is given mainly as an introduction to a second paper on a kindred subject.

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On the Phenomena exhibited by a Planet in its Transit across the Solar Disk, from Observations made by M. Ch. André.

By the Rev. S. J. Perry.

The results contained in this paper have a special interest at the present time, as the experiments were made with the direct view of securing accuracy of observation at the transit of *Venus* in 1882. We have but a short time for making all the necessary preliminary preparations for this, our only remaining chance of testing the value of the transit of *Venus* methods for determining the solar parallax, and it is, therefore, well to learn what is being done elsewhere both as a guidance and as a spur.

The expedition of the Italians to India in 1874 was undertaken mainly with the object of testing the spectroscopic methods of observing the coming transit, and the volume printed by Signor Tacchini shows the success of their endeavours, and serves as an admirable guide for those who would prepare themselves for a fruitful campaign in 1882. Last summer I found that my own spectroscopes gave very satisfactory results with one of the methods; and I purpose examining the others more in detail and under varying circumstances during the coming year.

The experiments of M. André are being made under the most advantageous circumstances. The splendid subterranean basement of the École Normale at Paris is placed at his disposal, and there, in a passage considerably more than 100 meters in length, he has established his apparatus. This consists of a model of the transit of an inferior planet; the planet being moved by clockwork, and passing across the bright field backwards and forwards, without the necessity of any personal adjustment, and registering each contact electrically on a chronograph. The bright field which represents the Sun is illuminated by a Drummond light, and as a supply of oxygen is always at hand, a special pipe having been kindly laid down by M. H. Ste. Claire de Ville from his chemical laboratory overhead, no delay or loss of time is ever experienced; an advantage that will be fully appreciated by those who have made similar observations in the open air, with the Sun itself as the source of light. Three telescopes are mounted at the distance of about 100 meters from the model, and the chronograph is established in an adjoining passage. The method of observing is too obvious and too familiar to need any explanation here. It will suffice to give at once the conclusions at which M. André has arrived, which I will take from a letter received from him towards the end of last month.

1. The bridge, black ligament, or black drop, as it is variously called, is a necessary phenomenon under certain circumstances, and not merely accidental. With an unchanging source of light of sufficient brilliancy the angular dimensions of

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the ligament are inversely proportional to the diameter of the object-glass, and with an aperture of 5-inches, the drop is scarcely perceptible. Diaphragms should never be used when observing *Venus* in transit, as the apparent dimensions of the drop are augmented by any increase in the focal length.

2. It is always possible to get rid of the ligament, and reduce the phenomena to geometrical contacts, either

(*a*) by reducing sufficiently the intensity of the source of light, or augmenting the absorbing power of the dark-glass employed; or again

(*b*) by covering the object-glass with a network diaphragm, composed of rings alternately full and empty, and all very thin, but bearing a certain proportion to the focal length of the lens.

3. The defect of imperfect focussing has but little influence on the result, the phenomena changing little as long as a fair focus is obtained.

4. Atmospheric undulations, on the other hand, have a considerable influence. They tend to give the image of the planet every description of strange form, and to them are due the contacts at several points at the same time, of which so much has been said. These are entirely got rid of by coating one of the surfaces of the object-glass with a thin film of silver.

5. Even when the object-glass is so small, and the dark-glass so thin, that the ligament is still present, the observation may still by good training be made very precisely. One phase of the phenomenon is simultaneous for all apertures, and can be estimated without difficulty to within $0^{s}.75$ for interior contact at ingress, and $1^{s}.5$ at egress, thus leaving a probable total error of $2^{s}.25$ in the observed duration of the transit.

6. In order to secure the solar parallax to within $0''.01$, it suffices that the error in the duration of transit should not exceed 5^{s}; a small telescope may, therefore, serve to determine this parallax to within $0''.005$. Halley was not then mistaken in his estimate of the great value of his method.

7. The above results agree perfectly with the theory of instrumental diffraction, and can be rigorously deduced from it. To effect this, it is only necessary to draw the geometrical phenomenon as it presents itself at the different epochs of the transit, and to measure the portion of the volume of the solid of diffraction comprised between *Venus* and the Sun's edge. M. André has made the calculations for the epochs 10^{s}, 5^{s}, 0^{s}, and from the beginning and end of the transit.

8. The phenomena are the same for *Mercury* as for *Venus*, but the magnifying power must be greater for *Mercury*, almost double.

The difficulties that have so far surrounded the observation of the transit of *Venus* have arisen mainly from the preconceived idea expressed in the sole word "Contact." The phenomenon could have been geometrical contact only in a restricted

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number of cases; and certainly our best results are such remarks as those of F. Hell, when he describes the breaking of the bright line; his words are clear, frank, and precise.

Besides giving the telescope a sufficient aperture, the maximum amount of light should also be obtained. It would be well, therefore, if possible to determine accurately beforehand the exact thickness of dark-glasses most suitable for the observation of the coming transit of *Venus*, and this might be obtained experimentally at the previous transit of *Mercury*. This last question of the dark-glass, which seems hitherto to have been considered but of little moment, is in reality one of the most important conditions in the observation.

If I might add one remark to these useful conclusions of M. André, I should think it would be well to make experiments also as to the tint of coloured glass best suited for diminishing the light of the photosphere, without altering considerably that of the chromosphere, in order to give some value to the first external contact. Dr. Janssen has already shown us the feasibility of this plan, and demonstrated that the spectroscope is not required in order to see *Venus* on the bright background of the chromosphere.

On the Orbit of α Centauri. By A. Marth, Esq.

(*From a Letter to E. Dunkin, Esq., F.R.S.*)

At the close of the last meeting of the Royal Astronomical Society you proposed that I should furnish in writing the substance of some remarks on the Double Star *α Centauri*, which I had been permitted to address to the meeting just before.

Though it has been pointed out some years ago that the comes of *α Centauri* would reach its apparent periastre in the course of the year 1875; and though the great importance of securing series of good observations during the preceding and following years is recognised and appreciated by all who keep themselves informed on the subject of binary stars; there seems cause to apprehend that the observers in the Southern Hemisphere, who alone are favourably situated for making such observations, have persisted in their strange neglect of this the most interesting of all double stars. Thinking that it might do some good, and could do no harm, if the subject were brought before the meeting, and if the personal friends of the Southern observers were appealed to for their friendly assistance, I asked leave to occupy a few minutes before the adjournment with a short statement of the circumstances of the case, and to exhibit a diagram which would render any detailed explanation superfluous. In order to enable readers of this letter to reconstruct the diagram (and they will find it far more instructive and satisfactory if they themselves

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draw it on a larger scale on squared paper than if they got it ready printed on a small scale), I subjoin the rectangular co-ordinates of a sufficient number of points of both the true and the apparent orbits, so that the two ellipses may be easily drawn by hand. The co-ordinates have been deduced from Mr. Powell's elements published in the *Monthly Notices*, vol. xxx. page 192, the line of nodes common to both ellipses being taken as the basis. The x co-ordinates are consequently the same for both ellipses, while the (y) co-ordinates of the projected or apparent ellipse have a constant ratio to the y co-ordinates of the true ellipse. The first column of the table contains the corresponding true anomalies v of the comes:—

v °	x "	(y) "	y "	
300·80	+ 8·96	0	0	Node.
330	+ 6·69	+ 3·74	+0·57	
0	+ 3·72	+ 6·23	+0·95	Perihelion.
30·80	0	+ 7·68	+1·17	
49·91	− 2·76	+ 7·96	+1·22	Maximum of y.
70	− 6·17	+ 7·57	+1·15	
90	−10·22	+ 6·09	+0·93	
110	−14·96	+ 2·85	+0·44	
120·80	−17·96	0	0	Node.
129·75	−19·88	− 3·13	−0·48	End of minor axis.
140	−22·03	− 7·67	−1·17	
154·12	−23·41	−15·39	−2·35	Maximum of x.
170	−21·00	−24·33	−3·71	
180	−16·90	−28·35	−4·33	Aphelion.
191·69	−10·42	−30·08	−4·59	Maximum of y.
200	− 5·59	−29·29	−4·47	
210·80	0	−26·40	−4·03	
220	+ 3·73	−23·02	−3·51	
230·25	+ 6·70	−18·98	−2·90	End of minor axis.
240	+ 8·54	−15·27	−2·33	
250	+ 9·63	−11·80	−1·80	
267·48	+10·23	− 6·73	−1·03	Maximum of x.
270	+10·22	− 6·09	−0·93	
290	+ 9·59	− ·	−0·28	
Centre of ellipse	− 6·59	−11·06	−1·69	

The circle of declination passes through the points—

	x = "	y = "
North	+20	− 9·03
South	−20	+ 9·03

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The co-ordinates of the chief positions of the comes, which have been deduced from observations, and have been published, are the following (*vide Monthly Notices*, vols. xv. p. 88, xvi. p. 120, xvii. p. 19, xxiv. p. 170, and *Memoirs*, vols. xxiv. xxv. and xxxii.)

Time.	x	y	Observer.	Place.
	"	"		
1826·012	−22·18	−3·47	Dunlop	Paramatta
30·012	−19·60	−3·71	Johnson	St. Helena
34·79	−16·87	−4·27	Herschel	Feldhausen
37·34	−15·46	−4·55	,,	,,
46·866	− 8·50	−4·91	Jacob	Madras
48·023	− 6·70	−4·46	,,	,,
50·926	− 4·12	−4·33	,,	,,
53·049	− 2·05	−4·06	,,	,,
54·003	− 1·30	−4·01	Jacob & Powell	,,
55·318	+ 0·09	−4·07	Powell	,,
56·015	+ 0·54	−3·77	Jacob	,,
56·591	+ 1·11	−3·72	,,	,,
59·382	+ 3·67	−3·57	Powell	,,
60·114	+ 4·41	−3·58	,,	,,
60·479	+ 4·55	−3·26	,,	,,
61·052	+ 5·08	−3·33	,,	,,
61·305	+ 5·31	−3·20	,,	,,
61·576	+ 5·45	−3·15	,,	,,
62·205	+ 6·09	−3·01	,,	,,
63·028	+ 6·63	−2·80	,,	,,
64·110	+ 7·44	−2·50	,,	,,
1870·1	+10·22	−0·69	,,	,,

Predicted Positions.

	x	y
	"	"
1872·0	+ 8·64	+0·11
73·0	+ 6·88	+0·52
74·0	+ 4·31	+0·89
75·0	+ 1·16	+1·13
76·0	− 2·17	+1·21
77·0	− 5·28	+1·18
1878·0	− 8·07	+1·07

The first four of these places have been observed in the Southern Hemisphere, all the others at Madras, where *α Centauri* does not reach an altitude of 17° above the horizon. Powell's

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published observations represent upwards of 2,000 single measures (*vide Memoirs*, vol. xxxii. p. 93). Of his later observations made after 1864, only the normal place for 1870–1 seems to have become publicly known. It is to be hoped that he may have been able to watch and observe the comes of his favourite double star through the most interesting portion of its orbit; but with the star so near the horizon and with a 4-inch telescope, the task cannot but have been beset with considerable difficulties. Mr. Powell will have deserved all the more credit and honour. It might fairly have been expected that observers who are provided with better instruments, and are far more favourably placed for observing *α Centauri*, would have rejoiced at having the opportunity of observing it just during those years when the observations are of the highest permanent value. If Mr. Powell's orbit and remarks were not sufficient to attract their attention, a glance over the Ephemeris deduced by Mr. Hind from Powell's elements, and published in the *Monthly Notices* for November 1872, vol. xxx. page 54, might have shown them the lucky and important chance within their grasp. The observations need not have interfered with other work, as they demand no fixed days and hours, and might have been made in daytime. But it seems that the most favourable time and opportunity has been allowed to slip away unused. However, as a couple of position-angles which Lord Lindsay has obtained in 1874 during his Mauritius expedition, are said to indicate that the comes of *α Centauri* is more than half a year behind its predicted position, the Southern observers may have a chance of regaining a portion of their neglected opportunities; and I suggested, therefore, that their personal friends should call their attention to the matter. But as you and other members of the Council have expressed the opinion that it would be better that I should put my remarks on paper for the *Monthly Notices*, I defer to your and their opinion, and I place accordingly these lines at your disposal, in the hope that they may be of some service.

1876, *December* 13.

A Preliminary List of Binary and other interesting Double Stars.

By J. M. Wilson, Esq., M.A., and J. Gledhill, Esq., F.R.A.S.

The following list is intended to be the basis of a working List of Binary and other interesting Double Stars, of which it is desirable to have accurate measures at not very distant intervals of time; and we think it may be of assistance to those observers who take up this branch of astronomy to have such a list for their guidance. We publish it also, with the hope that it may attract the attention of those who have specially devoted themselves to the measurement of binary stars, and that they will by their criticisms point out any errors that may exist in it, of

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omission or otherwise. It is our intention to offer to the Society, at no distant period a list of binaries and other interesting double stars, with all the measures of them, that have been published up to the present date, extracted from the various Memoirs, Transactions, Journals, etc., which an astronomer must now consult if he wishes to ascertain the past history of a binary star and compute its orbit. It is plainly desirable that this list should be as complete as possible, and we shall be greatly obliged to any one who will point out to either of us any omissions in this preliminary list.

With a view to this work, we formed, some years ago, a list of double stars for observation, selected from those observed by Σ, OΣ, Mädler, Dawes, Dembowski, Secchi, and others, and have measured them, in order to ascertain, in all doubtful cases, whether there was sufficient evidence of appreciable change having taken place since the earliest measures. In this way we have been enabled to strike off many that were classed as probable binaries by Mädler and Secchi, and have ascertained that others are in motion which were not previously given in lists of such objects. Clearly, however, no list published now, however perfect, can possibly be final; it can do no more than represent knowledge up to the present date.

In addition to the well-known Lists of Double-Star Measures, we have been enabled, at the request of the Rev. R. Main, to obtain from Herr Otto von Struve the yet unpublished Part I. of his forthcoming great work on Double Stars. The Part received contains the Pulkova measures of Σ's Double Stars. Part II., containing the re-examination of OΣ's own discoveries, is expected shortly. We have found this work of very great help in deciding several doubtful points.

The numerous close pairs discovered by Mr. S. W. Burnham, of which measures have been published, will be entered on this list. There can be but little doubt that these interesting and difficult stars will shortly yield a rich harvest of binaries.

A few words on the form of the list may here be given. The first column contains the reference number; the second, the name of the star; the third, Σ's or OΣ's number (the latter in brackets) where the star has been observed by either; the fourth, the number in Sir John Herschel's great Catalogue, lately edited by the Rev. R. Main and Prof. Pritchard.

In conclusion, the points on which we request information are—

(1) Binaries omitted which it is thought should appear in such a list.

(2) Criticisms on the insertion of any stars which it is thought should be omitted.

(3) Unpublished measures or orbits of any binary stars.

Communications may be sent to J. M. Wilson, Temple Observatory, Rugby; or to Mr. J. Gledhill, Mr. E. Crossley's Observatory, Halifax.

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No.	Name of Star.	Σ's No.	H's No.
1	Cephei 316 (B)	2	2
2	... ...	[2]	35
3	Cephei 318 (B)	13	48
4	... ...	16	58
5	... ...	[4]	59
6	... ...	23	66
7	26 Andromedæ	[5]	76
8	42 Piscium ...	27	103
9	Cassiopeiæ 49 (B)	30	127
10	49 Piscium ...	32	156
11	λ Cassiopeiæ ...	[12]	162
12	... ...	[18]	242
13	η Cassiopeiæ ...	60	283
14	... ...	69	307
15	36 Andromedæ...	73	319
16	P. O. 251 ...	80	344
17	... ...	86	373
18	Ceti 160 (B) ...	91	393
19	Polaris ...	93	400
20	... ...	[24]	407
21	... ...	[28]	430
22	... ...	102	453
23	42 Ceti ...	113	474
24	... ...	118	502
25	... ...	122	514
26	... ...	125	515
27	... ...	132	542
28	Andromedæ 219 (B)	133	543
29	P. I. 123 ...	138	568
30	... ...	142	588
31	... ...	[35]	606
32	... ...	158	637
33	... ...	175	677
34	... ...	183	704
35	... ...	185	710
36	P. I. 209 ...	186	714
37	... ...	196	738
38	α Piscium ...	202	753
39	γ Andromedæ ...	[38]	755

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No.	Name of Star.	Σ's No.	H's No.
40	10 Arietis ...	208	761
41	... ...	221	799
42	Andromedæ 259 (B)	228	818
43	66 Ceti ...	231	821
44	... ...	234	827
45	... ...	257	892
46	ι Cassiopeiæ ...	262	906
47	... ...	278	949
48	84 Ceti ...	295	1009
49	θ Persei ...	296	1010
50	γ Ceti ...	299	1019
51	Arietis 114 (B)	305	1036
52	... ...	312	1044
53	π Arietis ...	311	1047
54	Persei 85 (B) ...	314	1053
55	... ...	[48]	1058
56	... ...	326	1080
57	... ...	328	1084
58	ε Arietis ...	333	1098
59	... ...	334	1104
60	Persei 104 (B)...	336	1109
61	Procyon		
62	... ...	[50]	1132
63	... ...	355	1147
64	... ...	367	1179
65	... ...	377	1210
66	... ...	380	1222
67	... ...	388	1240
68	... ...	400	1270
69	... ...	403	1271
70	... ...	408	1279
71	7 Tauri ...	412	1288
72	P. III. 98 ...	422	1308
73	... ...	447	1370
74	P. III. 165 ...	[64]	1387
75	Cephei 49 (Hev.)	460	1406
76	32 Eridani ...	470	1436
77	P. III. 242 ...	[531]	1486
78	... ...	511	1528

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No.	Name of Star.	Σ's No.	H's No.
79	... ...	[78]	1540
80	40 Eridani ...	518	1553
81	... ...	[79]	1571
82	... ...	[80]	1582
83	Tauri 230 (B) ...	535	1600
84	... ...	[82]	1602
85	... ...	[85]	1677
86	2 Camelopardali	566	1687
87	... ...	567	1690
88	... ...	577	1715
89	... ...	615	1831
90	... ...	619	1842
91	5 Aurigæ	[92]	1844
92	... ...	[93]	1862
93	... ...	629	1871
94	Camelopardali 19 (Hev.)	634	1892
95	P. IV. 288 ...	[95]	1897
96	... ...	[97]	1903
97	14 Orionis (i) ...	[98]	1923
98	... ...	644	1925
99	... ...	[100]	1941
100	... ...	651	1947
101	λ Aurigæ ...	...	1991
102	... ...	676	2001
103	... ...	677	2005
104	η Orionis ...	...	2071
105	... ...	712	2091
106	32 Orionis ...	728	2133
107	Tauri 380 (B) ...	742	2165
108	θ^1 Orionis ...	748	2178
109	... ...	749	2182
110	... ...	[112]	2150
111	ζ Orionis ...	774	2235
112	... ...	3115	2237
113	... ...	853	2462
114	... ...	861	2475
115	4 Lyncis ...	881	2527
116	... ...	932	2695
117	... ...	945	2730

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No.	Name of Star.	Σ's No.	H's No.
118	54 Aurigæ ...	[152]	2734
119	12 Lyncis ...	948	2749
120	... ...	3117	2757
121	... ...	[154]	2766
122	... ...	[155]	2785
123	... ...	[156]	2795
124	Sirius ...	...	2799
125	14 Lyncis ...	963	2802
126	... ...	[157]	2811
127	13 Lyncis ...	[159]	2851
128	... ...	[161]	2869
129	38 Geminorum (*e*)	982	2872
130	μ Canis Majoris	997	2899
131	Σ 1037 ...	[166]	3012
132	... ...	1049	3040
133	P. VII. 52 ...	[170]	3068
134	δ Geminorum ...	1066	3084
135	... ...	1071	3092
136	... ...	1074	3103
137	... ...	1076	3107
138	... ...	1081	3121
139	... ...	1091	3158
140	... ...	1093	3161
141	... ...	1104	3214
142	Castor ...	1110	3228
143	P. VII. 170 ...	1126	3297
144	κ Geminorum ...	[179]	3321
145	... ...	1136	3340
146	... ...	1142	3354
147	... ...	1157	3420
148	... ...	[186]	3482
149	Lyncis 85 (B) ...	1187	3533
150	ζ Cancri ...	1196	3557
151	P. VIII. 13 ...	1202	3572
152	... ...	1216	3646
153	... ...	[193]	3696
154	... ...	1263	3832
155	ε Hydræ ...	1273	3868
156	... ...	1287	3907

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No.	Name of Star.	Σ's No.	H's No.
157	ι Ursæ Majoris	[196]	3943
158	... ...	1300	3970
159	σ^2 Ursæ Majoris	1306	3989
160	... ...	1316	4021
161	... ...	1321	4046
162	... ...	3121	4083
163	Lyncis 157 (B)...	1338	4101
164	... ...	[200]	4123
165	... ...	[201]	4128
166	Hydræ 116 (B)...	1348	4139
167	ω Leonis ...	1356	4165
168	Hydræ 134 (B)...	1365	4190
169	P. IX. 161 ...	1377	4253
170	φ Ursæ Majoris	[208]	4290
171	... ...	1385	4294
172	... ...	1389	4305
173	8 Sextantis ...	A.C. 5	4314
174	... ...	1406	4387
175	... ...	[213]	4429
176	P. X. 23 ...	[215]	4449
177	γ Leonis ...	1424	4469
178	Leonis 145 (B)...	1426	4477
179	... ...	1439	4536
180	... ...	1457	4606
181	P. X. 128 ...	[224]	4612
182	... ...	1472	4669
183	... ...	[228]	4671
184	... ...	[229]	4690
185	... ...	1486	4714
186	... ...	[230]	4717
187	54 Leonis ...	1487	4719
188	... ...	1500	4754
189	P. X. 229 ...	1504	4782
190	... ...	1514	4820
191	[539] ...	1516	4833
192	P. XI. 9 ...	1517	4834
193	ξ Ursæ Majoris	1523	4860
194	... ...	1534	4885
195	ι Leonis ...	1536	4896

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No.	Name of Star.	Σ's No.	H's No.
196	57 Ursæ Majoris	1543	4924
197	... ...	[234]	4934
198	... ...	[235]	4942
199	P. XI. 111 ...	1555	4978
200	... ...	[237]	5000
201	... ...	1588	5141
202	... ...	3123	5167
203	... ...	1607	5205
204	Comæ Ber. 68 (B)	1639	5293
205	... ...	1641	5296
206	... ...	1644	5307
207	Virginis 191 (B)	1647	5319
208	... ...	1658	5341
209	... ...	1663	5354
210	γ Virginis ...	1670	5377
211	... ...	1678	5401
212	35 Comæ Ber. ...	1687	5430
213	... ...	[256]	5445
214	179 Comæ Ber.	1722	5515
215	42 Comæ Ber. ...	1728	5523
216	... ...	[261]	5535
217	... ...	1734	5570
218	... ...	1742	5590
219	... ...	1746	5608
220	72 Virginis l^1 ...	1750	5622
221	P. XIII. 127 ...	1757	5639
222	25 Canum Ven.	1768	5673
223	84 Virginis ...	1777	5704
224	... ...	1781	5726
225	τ Boötis ...	[270]	5737
226	... ...	1785	5754
227	P. XIII. 238 ...	1788	5789
228	[277] ...	1812	5894
229	... ...	1819	5907
230	... ...	1820	5913
231	Boötis 121 (B)...	1825	5922
232	... ...	1830	5933
233	... ...	1832	5934
234	P. XIV. 70 ...	1837	5964

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No.	Name of Star.	Σ's No.	H's No.
235	... ...	1842	5987
236	... ...	1858	6040
237	... ...	1863	6062
238	π Boötis ...	1864	6066
239	ζ Boötis ...	1865	6069
240	... ...	1866	6072
241	... ...	1876	6099
242	ε Boötis ...	1877	6101
243	... ...	1879	6106
244	... ...	1883	6124
245	ξ Boötis ...	1888	6146
246	... ...	[287]	6159
247	... ...	[288]	6161
248	44 Boötis (i) ...	1909	6237
249	... ...	1925	6305
250	... ...	[295]	6311
251	5 Serpentis ...	1930	6327
252	Coronæ 1 (B) ...	1932	6331
253	... ...	1934	6336
254	η Coronæ ...	1937	6362
255	P. XV. 74 ...	1938	6371
256	... ...	1944	6382
257	... ...	[296]	6388
258	δ Serpentis ...	1954	6426
259	... ...	1957	6434
260	... ...	[298]	6446
261	... ...	1961	6440
262	γ Coronæ ...	1967	6469
263	... ...	1983	6523
264	... ...	1985	6535
265	18 π^2 Ursæ Minoris	1989	6547
266	...	[303]	6575
267	ξ Libræ ...	1998	6582
268	κ Herculis ...	2010	6610
269	49 Serpentis ...	2021	6634
270	... ...	2022	6640
271	... ...	2026	6645
272	σ Coronæ ...	2032	6654
273	Antares ...	...	6707

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No.	Name of Star.	Σ's No.	H's No.
274	... ...	2049	6718
275	Draconis 99 (B)	2054	6723
276	λ Ophiuchi ...	2055	6727
277	ζ Herculis ...	2084	6799
278	... ...	2094	6816
279	... ...	2097	6823
280	21 Ophiuchi ...	[315]	6840
281	... ...	2106	6842
282	Herculis 167 (B)	2107	6847
283	... ...	3107	6867
284	... ...	[321]	6879
285	P. XVI. 270 ...	2114	6888
286	20 Draconis ...	2118	6895
287	Herculis 210 (B)	2120	6910
288	μ Draconis ...	2130	6935
289	36 Ophiuchi ...	...	6946
290	δ Herculis ...	3127	6968
291	... ...	2145	6973
292	ρ Herculis ...	2161	7016
293	... ...	2165	7028
294	... ...	2173	7040
295	P. XVII. 163 ...	2190	7076
296	... ...	2199	7104
297	... ...	2203	7108
298	... ...	2205	7128
299	... ...	2214	7129
300	... ...	2215	7130
301	μ Herculis (A. C. 7)	2220	7142
302	τ Ophiuchi ...	2262	7245
303	... ...	2267	7262
304	... ...	2271	7267
305	70 *p* Ophiuchi ...	2272	7273
306	73 Ophiuchi ...	2281	7309
307	Herculis 417 (B)	2289	7322
308	... ...	2294	7340
309	Lalande 33731 ...	2303	7370
310	... ...	2311	7388
311	Herculis 452 (B)	2315	7406
312	39 Draconis, *b* ..	2323	7425

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No.	Name of Star.	Σ's No.	H's No.
313	φ Draconis ...	[353]	7443
314	... ...	[358]	7479
315	α Lyræ ...	...	7501
316	... ...	2367	7523
317	... ...	2384	7563
318	ϵ^1 Lyræ ...	2382	7564
319	ϵ^2 Lyræ ...	2383	7566
320	... ...	2396	7593
321	... ...	2400	7604
322	... ...	2402	7609
323	... ...	2409	7625
324	o Draconis ...	2420	7660
325	[365] ...	3130	7670
326	... ...	2422	7671
327	11 Aquilæ ...	2424	7675
328	... ...	2429	7689
329	P. XVIII. 274...	2434	7702
330	... ...	2437	7706
331	P. XVIII. 287...	2438	7709
332	... ...	2441	7723
333	... ...	2454	7752
334	Lalande 35821...	2455	7753
335	... ...	2464	7768
336	... ...	2471	7787
337	... ...	2481	7810
338	... ...	2484	7819
339	Cygni 6 ...	2486	7828
340	... ...	2491	7854
341	... ...	2514	7922
342	P. XIX. 128 ...	2521	7946
343	Cygni 22 (B) ...	2525	7958
344	... ...	2538	8006
345	P. XIX. 185 ...	2541	8024
346	... ...	2544	8037
347	... ...	[378]	8061
348	... ...	2556	8079
349	... ...	[383]	8123
350	... ...	2574	8139

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No.	Name of Star.	Σ's No.	H's No.
351	... ...	2576	8146
352	δ Cygni ...	2579	8153
353	... ...	[387]	8179
354	β Aquilæ ...	[532]	8228
355	Cygni 116 (B) [392]	2607	8274
356	... ...	2619	8313
357	θ Sagittæ ...	2637	8382
358	... ...	2640	8386
359	... ...	[400]	8411
360	... ...	2658	8457
361	P. XX. 178 [407]	2690	8600
362	... ...	2696	8624
363	β Delphini ...	2704	8663
364	κ Delphini ...	[533]	8674
365	... ...	2708	8692
366	... ...	[410]	8703
367	... ...	2725	8751
368	52 Cygni ...	2726	8755
369	λ Cygni ...	[413]	8773
370	4 Aquarii ...	2729	8784
371	... ...	2734	8812
372	ε Equulei ...	2737	8839
373	... ...	2744	8860
374	... ...	2746	8868
375	... ...	2749	8876
376	61 Cygni ...	2758	8898
377	... ...	2760	8902
378	δ Equulei [535]	2777	8959
379	... ...	2779	8965
380	P. XXI. 50 ...	[432]	8976
381	A. C. 19 ...	...	8998
382	... ...	2793	9048
383	... ...	[437]	9021
384	Pegasi 20 (B) ...	2799	9072
385	... ...	2801	9087
386	Pegasi 29 (B) ...	2804	9107
387	... ...	[443]	9134
388	... ...	[447]	9175

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No.	Name of Star.	Σ's No.	H's No.
389	μ Cygni ...	2822	9210
390	... ...	2825	9226
391	... ...	2828	9240
392	... ...	2837	9273
393	... ...	2849	9333
394	... ...	2865	9416
395	P. XX. 11, 12 ...	2872	9442
396	P. XXII. 33 ...	2877	9469
397	Pegasi 148 ...	2878	9466
398	... ...	2895	9516
399	33 Pegasi ...	2900	9539
400	ζ Aquarii ...	2909	9580
401	37 Pegasi ...	2912	9593
402	... ...	2915	9614
403	... ...	2928	9670
404	... ...	2934	9703
405	... ...	2942	9736
406	P. XXII. 219 ...	2944	9742
407.	... ...	[536]	9832
408	52 Pegasi ...	[483]	9840
409	... ...	2976	9901
410	... ...	2990	9946
411	94 Aquarii ...	2998	9982
412	o Cephei ...	3001	9993
413	... ...	3006	10004
414	... ...	3007	10015
415	P. XXIII. 69 ...	3008	10020
416	... ...	[500]	10117
417	... ...	3037	10170
418	... ...	3046	10235
419	37 Andromedæ (B)	3050	10258
420	Lalande 47206...	3056	10291
421	... ...	3062	10304
422	... ...	[523]	

The following stars, having common proper motion (see Struve's *Pos. Med.*) may, perhaps, be measured occasionally with advantage, and should therefore be inserted in the list. The distances are between 32″ and 7′: 40 *Eridani*, ψ *Aquarii*, 37 *Ceti*,

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Regulus, 16 *Cygni*, *Castor*, ν^1, ν^2 *Draconis*, 1 *Pegasi*, ι *Boötis*, 93 *Leonis*, μ *Boötis*, θ^1, θ^2 *Tauri*, ε and 5 *Lyræ*, α *Tauri*, 6 and 8 *Vulpec.*, 16 and 17 *Draconis*, 33 and 34 *Ophiuchi*, α^1 and α^2 *Capricorni*; also P. III. 241 and 50 *Persei* (see O Σ and Argelander).

In addition to the above, a good many pairs, whose changes in angle and distance can be explained by the proper motion of the principal star, were long ago examined by Struve (*Pos. Med.*) Perhaps these should go into the list. Also the "higher systems" of Mädler would probably not be misplaced in it (see *Untersuchungen über die Fixstern-Systeme.*

Mr. E. Crossley's Observatory,
Bermerside, Halifax,
December 1876.

On an Oversight in the Mécanique Céleste, and on the Internal Densities of the Planets. By George H. Darwin, M.A., Fellow of Trinity College, Cambridge.

(*Communicated by J. W. L. Glaisher, F.R.S.*)

In the following paper an endeavour is made to point out an inconsistency, which appears to have escaped the notice of Laplace, in his determination of the precessional constants of the planets *Jupiter* and *Saturn*. From this I have been led on to speculate on the law of internal density of those planets, and of *Mars*, and to make some reference to the ellipticities of *Mercury* and *Venus*.

1. *Laplace's Law of the Internal Density of the Planets.*

In the investigation of the figure of the Earth, Laplace assumed that, in molten rock, the hydrostatic pressure *plus* a constant varies as the square of the density. The result of this assumption is that, after the consolidation of a planet, the density of any stratum of mean radius r is given by the law $\frac{\mathrm{F}}{r}\sin\frac{r\theta}{a}$, where a is the mean radius of the surface, and θ and F are constants.

Throughout the rest of this paper, besides the foregoing, the following notation is used:—

a, β, the equatoreal and polar radii;
ε the ellipticity of the surface;
m the ratio of the centrifugal force of the planet's rotation at the distance a to the mean pure gravity;

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f the ratio of the mean to the surface density;
C, A, the greatest and least principal moments of inertia of the planet;
P or $\frac{C-A}{C}$ the precessional constant; and
M the mass.
Other symbols will be defined as they arise.

Then the results of the Laplacian law may be embodied in the following equations*:—

$$\frac{f}{3} = \frac{1}{\theta^2} - \frac{\cot\theta}{\theta} \quad \ldots\ldots\ldots\ldots (1)$$

$$\frac{5m}{2\epsilon} = \frac{f\theta^2}{3(f-1)} - \frac{3}{f} \quad \ldots\ldots\ldots\ldots (2)$$

$$C-A = \frac{2}{3}\left(\epsilon - \frac{m}{2}\right) Ma^2 \quad \ldots\ldots\ldots\ldots (3)$$

$$C = \frac{2}{3}\left\{1 - \frac{6(f-1)}{f\theta^2}\right\} Ma^2 \quad \ldots\ldots\ldots\ldots (4)$$

$$\frac{\epsilon - \frac{m}{2}}{P} = 1 - \frac{6(f-1)}{f\theta^2} \quad \ldots\ldots\ldots\ldots (5)$$

Now, if (following Thomson and Tait) we take for the Earth $f = 2{\cdot}1$, which corresponds with $\theta = 144°$, we have

$$P = 1{\cdot}994\left(\epsilon - \frac{m}{2}\right) \quad \ldots\ldots\ldots\ldots (6)$$

$$\frac{5m}{2\epsilon} = 2{\cdot}562 \quad \ldots\ldots\ldots\ldots (7)$$

Hence, in any planet where the law of density is the same as in the Earth (i.e., $f = 2{\cdot}1$, $\theta = 144°$), we should find (7) satisfied, and (6) would give the precessional constant.

In order to illustrate the Laplacian law, the following table has been constructed, giving the values of f and $\frac{5m}{2\epsilon}$ for every 10° of θ, with the omission of a few at the early part, which are rather troublesome to calculate, and are of little value.

* See Thomson and Tait, *Nat. Phil.* §§ 824, 827. Equation (3) is independent of Laplace's assumption.

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θ	f	$\frac{5m}{2\epsilon}$	θ	f	$\frac{5m}{2\epsilon}$
0°	1·0000	2·000	90°	1·2159	2·165
10			100	1·2879	2·213
20	1·0082		110	1·3827	2·270
30	1·0188		120	1.5109	2·338
40	1·0341	2·029	130	1·6922	2·422
50	1·0548	2·046	140	1·9657	2·525
60	1·0817	2·067	150	2·4225	2·652
70	1·1161	2·094	160	3·3363	2·813
80	1·1600	2·126	170	6·0750	3·019
90	1·2159	2·165	180	infin.	3·290

This table shows how $\frac{5m}{2\epsilon}$ increases, as the planet passes from homogeneity to infinitely small surface density; $\frac{5m}{2\epsilon}$ can never be less than 2, nor greater than 3·290. Although it is not strictly involved in the subject of this paper, I may point out that the first column of the table may be employed to calculate the ellipticity of any internal stratum. I have shown elsewhere* that the ellipticity e of any stratum of mean radius $\frac{\theta'}{\theta}a$ is given by,—

$$\frac{e}{\epsilon} = \left(\frac{\theta}{\theta'}\right)^2 \frac{f(f'-1)}{f'(f-1)},$$

where f, θ refer to the surface, and f' is the value corresponding to θ' in the table. For example, to find the ellipticity of the Earth's stratum of mean radius $\frac{5}{12}a$, we must take $\theta' = 60°$, because $\theta = 144°$; then from the table $f' = 1·0817$, and

$$e = \epsilon \left(\frac{12}{5}\right)^2 \cdot \frac{2·1 \times ·0817}{1·0817 \times 1·1} = \frac{\epsilon}{1·204}$$

$$= \frac{1}{357}, \text{ when } \epsilon = \frac{1}{297}.$$

2. *Jupiter's Precessional Constant.*

To determine the precessional constant Laplace uses the following argument:—"If we suppose the densities of the strata of Jupiter and the Earth, at distances proportional to the diameters of these planets, to be in a constant ratio to each other. . . In this hypothesis, if both planets be fluid, their ellipticities will be,

* *Messenger of Mathem.*, Nov. 1876, p. 109. The notation is, however, different.

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as in [2068 *k*, etc., III. v. § 43] proportional to the respective values of ϕ,* corresponding to each of them; or to their ellipticities, if they be homogeneous. If we suppose the ratio to obtain in their actual state, and we have seen in [2069, III. v. § 43] that this is nearly conformable to observation, *then the values of* $\frac{2C-A-B}{C}$ *will be, for each of these planets, respectively proportional to the ellipticities corresponding to the case of homogeneity.* These ellipticities by the same article [2068″], are as ·10967000 to 0·00433441." † He uses ·00291193 as the Earth's precessional constant, and thence deduces $\frac{2C-A-B}{C} = ·14735$, or in my notation P = ·07368.

By the theory of the perturbations of the Satellites, he finds $\epsilon - \frac{m}{2} = ·0219013$; ‡ this value does involve any assumption as to the law of internal density, except, I conceive, that the strata of equal density must be nearly spherical.§

Then by the periodic time of the Fourth Satellite, and its observed distance from *Jupiter*, he finds $m = ·0987990$; whence $\epsilon = ·0713008$.‡

Using these values of m and ϵ, we get $\frac{5m}{2\epsilon} = 3·4642$. Now Laplace does not seem to have noticed that these values are not only incompatible with the identity of the law of internal density in the *Earth* and *Jupiter*, but are also incompatible with that form of law at all; for, as appears from the table, $\frac{5m}{2\epsilon}$ can never be greater than 3·290.

My attention was first drawn to the point by observing that, if there were this identity of law of density, the precessional constant of *Jupiter* ought to be nearly twice $\epsilon - \frac{m}{2}$, or ·0438; whereas Laplace, by a different method, founded on the same assumption, finds it to be ·0737. This of course indicated that the assumption was untenable.

In view of this discrepancy, it will be well to go over Laplace's work again by the light of later, and presumably better observations.

The distance of the Fourth Satellite is open to some doubt, but the following has seemed to me the best value attainable. Bessel gives the apparent distance at the planet's mean distance the angles as 498·8663″.**

* The m of this paper.
† Bowditch, Trans. of *Méc. Cél.* VIII. vii., § 23.
‡ VIII. ix. § 27.
§ See Pratt's *Fig. of Earth*, Arts. 90–94.
** *Astron. Untersuch. Bestim. der Masse des Jupiter*, Königsberg 1842.

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M. Kaiser gives, as the result of a long series of his own observations when united with those of Bessel, that the polar and equatoreal diameters of *Jupiter* subtend at the same distance 35·170″ and 37·563″ respectively.*

Hence the mean distance D of the Satellite is 26·5616 equatoreal radii; or $D = 26{\cdot}5616\ a$; T, the satellite's periodic time is 16·68902 m. s. days, t, *Jupiter's* sidereal day is ·4135 m. s. days. Therefore

$$m = \left(\frac{T}{t}\right)^2 \left(\frac{a}{D}\right)^3 (1-\epsilon)$$

$$= {\cdot}0869258\,(1-\epsilon) = m'\,(1-\epsilon) \text{ suppose.}$$

Professor J. C. Adams informs me that M. Damoiseau has recalculated the values of $\epsilon - \frac{m}{2}$, and of the masses of the Satellites, basing his work on better observations than those which were available to Laplace.† He has taken, however, certain coefficients from Laplace, which ought to have been recalculated. This work has been completed by Professor Adams himself, and he has obtained the following value for $\epsilon - \frac{m}{2}$, of which he has, with very great kindness, allowed me to make use, viz.,

$$\epsilon - \frac{m}{2} = {\cdot}0216623‡$$

Substituting then for m, we have, for the ellipticity of *Jupiter*,—

$$\epsilon = \frac{\frac{m'}{2} + {\cdot}0216623}{1 + \frac{m'}{2}} = {\cdot}06241 = \frac{1}{16{\cdot}022},$$

and

$$m = m'\,(1-\epsilon) = {\cdot}081501.§$$

Laplace remarks** that the ellipticity of *Jupiter* may be found

* *Astron. Nachr.* 48, p. 111.

† *Tables des Satellites de Jupiter.* Bur. des Long., Bachelier, Paris 1836.

‡ The corresponding masses of the Satellites multiplied by 1000 are found by him to be:

·283113
·232355
·812453
·214880

They seem to bear hardly any relation to the ordinarily received values.

§ This value may be compared with ·08163 found by Plana, *Ast. Nach.* 36, p. 155.

** VIII. ix. § 27.

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by this method with greater accuracy than by the best observations. It is interesting, therefore, to observe how closely this value agrees with that of all the later observations. The following are the values given for the reciprocal of the ellipticity by—Secchi, 16·06 [*Ast. Nach.* 43, p. 142]; Kaiser, (i) 15·36, (ii) 15·98 [*Ast. Nach.* 45, p. 211]; Bessel and Kaiser, 15·70; Bessel, 15·73; Secchi, 15·99 [*Ast. Nach.* 48, p. 111]; Schmidt, 15·6 [*Ast. Nach.* 65, p. 102]; Main, 16·84 [*Month. Not. Ast. Soc.* 16, p. 142]. The reductions were in several cases made by myself.

It is, nevertheless, a curious coincidence that the value of ϵ found by Laplace agreed well with the older observations of Struve, who found $\epsilon = \frac{1}{13{\cdot}74}$. [*Ast. Nach.* 45, p. 211.]

Using the above value of m, I find (following Plana*) that on the hypothesis of homogeneity $\frac{\alpha}{\beta} = 1{\cdot}1164$ (compare with 1·116515 of Plana), and therefore the homogeneous ellipticity is ·10405. But the homogeneous ellipticity of the Earth is $\frac{1}{230{\cdot}433}$ (Plana); and the Earth's precessional constant is ·003272; hence, following Laplace's method, we should have for *Jupiter*,

$$\begin{aligned} P &= {\cdot}10405 \times 230{\cdot}433 \times {\cdot}003272 \\ &= {\cdot}078451. \end{aligned}$$

But if Laplace's assumption as to the internal density of *Jupiter* were justifiable, we ought to have by equation (6),

$$\begin{aligned} P &= 1{\cdot}994\left(\epsilon - \frac{m}{2}\right) = 1{\cdot}994 \times {\cdot}02166 \\ &= {\cdot}043. \end{aligned}$$

Thus these new values of the quantities involved leave as wide a discrepancy as before between the two values of P. Therefore, Laplace's method cannot be justified.

3. *The Internal Density of Jupiter.*

But this unjustifiability may be seen in another way, for the new values of m and ϵ give $\frac{5m}{2\epsilon} = 3{\cdot}2646$; and reference to equation (7) shows that this differs widely from the corresponding value for the Earth. It is not, however, inconsistent with the Laplacian form of law, as was the same function when Laplace's values of m and ϵ were used. In fact, I find, after some rather troublesome arithmetic, that $\frac{5m}{2\epsilon} = 3{\cdot}2646$ corresponds to $\theta = 179^\circ\ 11'\ 20''$ nearly, and to $f = 68$.

* All future references to M. Plana are to his paper in *Astr. Nachr.* 36. p. 154.

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Using these values of θ and f, I find by equation (5) that *Jupiter's* precessional constant $= 2{\cdot}528\left(\epsilon - \frac{m}{2}\right) = {\cdot}0548$; and this I take to be far nearer the truth than the value assigned by Laplace.

On account of the uncertainty in the determination of the quantity m, the above values of θ and f can, of course, have no claim to precision. In fact, if following Herschel, Loomis, and others, we take $\frac{D}{a} = 26{\cdot}99835$, we should find $\epsilon = \frac{1}{16{\cdot}52}$, $m = {\cdot}0778$, and $\frac{5m}{2\epsilon} = 3{\cdot}211$. This last corresponds to θ about 177° 42′, and f about 24.

The value of the precessional constant will, however, be but little changed, being $2{\cdot}489\left(\epsilon - \frac{m}{2}\right) = {\cdot}0539$.

Now it seems reasonable *à priori* to assume that the law of internal density within *Jupiter* is of the same *nature* as in the Earth, and from that assumption it follows that the surface density of *Jupiter* is vastly less than the mean: for it must, I think, be admitted that numerical values can be assigned to m and ϵ with some precision.

But the true meaning of this result would seem to be that the Laplacian law of density is not exact for *Jupiter*, but that that planet must be very much denser in the centre than at the surface. Is it not possible that *Jupiter* may still be in a semi-nebulous condition, and may consist of a dense central part with no well-defined bounding surface? Does not this view accord with the remarkable cloudy appearance of the disk, and the remarkable belts?

4. *Saturn.*

The preceding method cannot be applied very satisfactorily to the case of *Saturn*, on account of the uncertainty in all the quantities which enter into the determination of m and ϵ; but the balance of evidence appears to me decidedly in favour of his surface density being far less than the mean.

m may be best determined from the motion of *Japetus*.

There seems almost complete unanimity as to his periodic time, and I take T = 79·3296 m. s. days.

Two values are assigned for the sidereal day of *Saturn*, viz., ·4370 (Hansen), and ·4278 (Herschel) m. s. days, the latter being more generally accepted; I take then $t = {\cdot}430$.

There is a wide difference of opinion as to the mean distance D of *Japetus*, the estimates varying from $57{\cdot}4\,a$ (Jacob, *Mem. Astr. Soc.* vol. xxviii.) to $64{\cdot}359a$ (used by Herschel, Loomis, and others, and most generally accepted). I take $D = 62\,a$.

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The ellipticity seems fairly well determined at $\frac{1}{11}$.*

Using these quantities in the formula

$$m = \left(\frac{T}{t}\right)^2 \left(\frac{a}{D}\right)^3 (1-\epsilon),$$

I find

$$m = \cdot 131270 - \cdot 61056\, \delta t - \cdot 00635\, \delta \left(\frac{D}{a}\right) - \cdot 14281\, \delta\epsilon.$$

(i) If all the small variations are zero, and $\epsilon = \frac{1}{11}$, we get $\frac{5m}{2\epsilon} = 3 \cdot 610$.

(ii) Loomis, *Pract. Astron.*, Tables 33, 34.

$$t = \cdot 437, \quad \frac{D}{a} = 64 \cdot 359, \quad \epsilon = \frac{1}{10},$$

$$\delta t = \cdot 007, \quad \delta \frac{D}{a} = 2 \cdot 359, \quad \delta\epsilon = \cdot 01909,$$

then, $m = \cdot 1093$, $\frac{5m}{2\epsilon} = 2 \cdot 732$.

(iii) Hind's *Solar System*, pp. 103–4.

$$t = \cdot 4278, \quad \frac{D}{a} = 60 \cdot 3436, \quad \epsilon = \frac{1}{10 \cdot 28} \text{ according to Bessel},$$

$$\delta t = -\cdot 0022, \quad \delta \frac{D}{a} = -1 \cdot 6564, \quad \delta\epsilon = \cdot 00637,$$

then, $m = \cdot 1422$, $\frac{5m}{2\epsilon} = 3 \cdot 66$.

If we take $\epsilon = \frac{1}{9 \cdot 23}$ from the *Greenwich Observations*, $\frac{5m}{2\epsilon}$ will be slightly smaller.

(iv) Captain Jacob's *Madras Observations* give $\frac{D}{a} = 57 \cdot 4$, and $\delta \frac{D}{a} = -4 \cdot 6$, this with $\epsilon = \frac{1}{11}$ and all the other small variations zero, gives $m = \cdot 160$ and $\frac{5m}{2\epsilon}$ very nearly $4\frac{1}{4}$.

No doubt other values might be assigned to $\frac{5m}{2\epsilon}$ with equal

* I find the following in a paper by Mr. Grant (*Month. Not. Ast. Soc.* xiii. p. 195), where he reduces observations of apparent ellipticity to their real values, viz., Lassell $\frac{1}{11 \cdot 05}$, Main $\frac{1}{9 \cdot 227}$, De La Rue $\frac{1}{10 \cdot 611}$. The mean of all Bessel's observations would seem to be $\frac{1}{10 \cdot 20}$, but Mr. Hind (see below) assigns a slightly different value as Bessel's result.

Sir W. Herschel found $\frac{1}{10 \cdot 368}$ (see p. 79 of above vol.), but $\frac{1}{10 \cdot 384}$ is also attributed to him on the same page.

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plausibility, but I think (ii) and (iv) contain extreme values in the two directions, and the truth probably lies at some intermediate point. It is noticeable that even the value (ii) indicates a larger ratio of mean to surface density than in the Earth, namely 2·809 (corresponding to $\theta = 155^\circ\ 14'$), whilst all the other values are far outside the limits of admissibility under the Laplacian law.

I have tried also to find m from the motion of *Titan*. Taking

$$\frac{D}{a} = 21,\quad T = 15{\cdot}9454,\quad t = {\cdot}43,\quad \epsilon = \frac{1}{11},$$

I find

$$m = {\cdot}13648 - {\cdot}1174\,\delta t - {\cdot}0195\,\delta\frac{D}{a} - {\cdot}1485\,\delta\epsilon.$$

If the small increments are zero, $\frac{5m}{2\epsilon} = 3{\cdot}75$; and if the various possible values be assigned to them, the results will be found to be very similar to those given above.

The value of m assigned by Laplace is ·165970,* and this, together with the ellipticities $\frac{1}{9}$ and $\frac{1}{12}$, gives $\frac{5m}{2\epsilon}$ equal to 3·734 and 4·979 respectively, either value quite incompatible with the Laplacian law of density. The ellipticity of the planet had apparently not been observed in his time, and the numbers used by him involve an ellipticity of $\frac{1}{68{\cdot}6}$, which we now know is far too small.

Laplace makes *Saturn's* precessional constant $\frac{1}{2}$ of ·27934 or ·13967 (VIII. xvii. § 37), but this value is inconsistent with any of those given above for m and ϵ.

Taking $\epsilon = \frac{1}{11}$, $m = {\cdot}1313$, we have $\epsilon - \frac{m}{2} = {\cdot}0252$. It can hardly be supposed that *Saturn* is more nearly homogeneous than is the Earth, and if the law of density were the same we should, by (6), have P = ·050.

On the other hand, if the Laplacian law of density were to hold good, and if the surface density were zero—of course an ideal case†—we should have by (5),

$$\frac{\epsilon - \frac{m}{2}}{P} = 1 - \frac{6}{x^2} = \frac{1}{2{\cdot}5505},$$

or

$$P = 2{\cdot}5505 \times {\cdot}0252 = {\cdot}064.$$

* *Méc. Cél.* VIII. xvii. § 36.

† It may be observed, that to be thoroughly consistent we should have in this case, $P = {\cdot}663m = {\cdot}873\epsilon$, because $\frac{5m}{2\epsilon} = 3{\cdot}290$; but the method is here only used to find the limiting value of the coefficient of $\epsilon - \frac{m}{2}$.

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I conceive then, that *Saturn's* precessional constant must be very nearly equal to ·06, since the former of these values is certainly too small, whilst the latter is a little too large.

5. *Mars.*

Mars rotates in $24^h\ 37^m\ 22^s{\cdot}6$, or 1·025956 m. s. days, according to the elaborate observations of M. Kaiser.* His density is ·948 of that of the Earth.† The sidereal day is ·997270 m. s. days, and for the Earth m is $\frac{1}{289{\cdot}66}$; hence for *Mars*,

$$m = \frac{1}{\cdot 948}\left(\frac{\cdot 997270}{1{\cdot}025956}\right)^2 \frac{1}{289{\cdot}66}$$

$$= \cdot 0034409 = \frac{1}{290{\cdot}6}.‡$$

With respect to the ellipticity of the planet the most various estimates are given. Thus, for the reciprocal of the ellipticity I find, according to Loomis (*Pract. Astr.*, Table 33) 50; Main (*Month. Not. Ast. Soc.* xvi., p. 142) 62; Kaiser (Guillemin, *Le Ciel*, p. 257) 118; Arago, doubtfully, 32; Bessel failed to detect ellipticity in observations at Königsberg; and lastly, from observations of Dr. Winnecke, to which I shall recur below, 225 (*Ast. Nach.* 48, p. 97). According to Dr. Winnecke, M. Kaiser doubts whether Mr. Main's result represents any corresponding reality.

With an ellipticity of $\frac{1}{225}$, we have $\frac{5m}{2\epsilon} = 1{\cdot}93$, and with the other values of ellipticity, a very much smaller value.

Now a reference to the table in section 1 will show that not only is even the largest of these quantities incompatible with the Laplacian law of density, but they are also incompatible with the homogeneity of the planet. We should require the planet to decrease in density towards the centre, or actually to be hollow; and on any theory of original fluidity such a state of things is almost inconceivable.

The wide discrepancy between various observations shows that the results are to be very little depended on; and for the following reasons, I venture to think that all the above values of the ellipticity are almost worthless, but that Dr. Winnecke's is by

* See a paper by M. Julius Schmidt, *Ast. Nach.* 82, p. 333.

† Guillemin, *Le Ciel*, p. 257. The other details with respect to *Mars* are given on the authority of M. Kaiser, and this I presume is so also.

‡ Plana gives $\frac{1}{288{\cdot}84}$, using slightly different data; with Herschel's value of the density ·72, $m = \frac{1}{220{\cdot}7}$.

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far the nearest to the truth. He gives* as the equatoreal and polar apparent diameters, 9″·227 and 9″·186, subject to mean errors of ·045″ and ·032″ respectively.

From these measurements I find that the *probable error* of the ratio of the axes is ·0050441. The ratio itself is in decimals ·9955564, and therefore the ratio of the axes is ·9955564 ±·0050441. That is to say, it is an even chance that the ratio of the axes lies between the 1·0006 and ·990512. In other words, it results from Dr. Winnecke's observations that it is an even chance that the figure of *Mars* lies between a prolate spheroid, with an ellipticity of $\frac{1}{1667}$, and an oblate one with an ellipticity of $\frac{1}{105}$; the observed values give an ellipticity of $\frac{1}{225}$.

Dr. Winnecke himself says, "Es sprechen diese Messungen entschieden gegen eine Abplattung des *Mars*, die für das Berliner Instrument messbar wäre."

Now the telescope shows that *Mars* has an external physical constitution exceedingly like that of the Earth, and therefore there is a strong probability that its internal structure is somewhat the same. Seeing then that the observations of the best observers permit such very wide limits of error, and that the value of m can be assigned with some precision, I submit that there is a far better chance of being near the truth in trusting to indirect evidence than to direct observation, for the determination of the ellipticity. Assuming then that the law of internal density is the same as in the Earth, I find an ellipticity of $\frac{1}{298}$, and this, I venture to think, is nearer the truth than any of the above-quoted values derived from observation.

6. *Mercury, Venus.*

M. Plana assigns as the values of m for these planets, $\frac{1}{325{\cdot}82}$ and $\frac{1}{251{\cdot}54}$ respectively; and following the arguments used in the case of *Mars* (although they have not here equal force), we should assign to *Mercury* an ellipticity of about $\frac{1}{330}$, and to *Venus* of about $\frac{1}{260}$.

7. *Conclusion.*

The results arrived at may be summed up as follow:—

The values assigned by Laplace to the precessional constants of *Jupiter* and *Saturn* cannot be maintained; and the objections

* *Ast. Nach.* 48, p. 97. The observations are said to be reduced for "Phase und Refraction," but I do not see it expressly stated that they are corrected for the Earth's Martian declination.

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to them remain equally strong when later observations are consulted.

Professor Adams's calculation of $\epsilon - \frac{m}{2}$ gives, as the ellipticity of *Jupiter*, $\frac{1}{16{\cdot}02}$.

The surface density of *Jupiter* is far less than the mean, and he may perhaps still be in a semi-nebulous condition.

There is a considerable probability that the like is true of *Saturn*.

The value of *Jupiter's* precessional constant is about ·0548; and that of *Saturn* probably about ·06. No dependence is to be placed on the observations of the ellipticity of *Mars*, because of their wide limits of error. Indirect evidence of the ellipticity seems safer, and we are thereby led to assign to him an ellipticity of $\frac{1}{298}$. In the cases of *Mercury* and *Venus*, we have only indirect evidence to rely on, and these ellipticities are probably about $\frac{1}{330}$ and $\frac{1}{260}$.

In conclusion, I must add that if in any case I have underrated or neglected the work of important observers, or have overrated the worth of other observations, my excuse must be my previous slight acquaintance with observational astronomy.

Postscript.—The method of this paper may perhaps give some idea of the amount of difference which might be expected to be found between the apparent equatoreal and polar diameters of the Sun.

To find m, the Earth may be treated as a solar satellite, and the same formula as before applied. $\frac{d}{D}$ is here the Sun's mean apparent radius (which I take as 961″·82) in circular measure.

T = 365·2569 m. s. days.

t, according to Carrington, is 25·38 m. s. days.

But Mr. Christie (to whom I owe my thanks for his help in this matter) informs me that the true period may perhaps be 26 or 27 days. The following results are therefore given in duplicate; in those marked with an accent t is taken as 27.

Then m = ·00002100, or m' = ·00001829.

If the law of internal density were the same as in the Earth, we should have,

ϵ = ·00002048, or ϵ' = ·00001784.

These correspond to differences of apparent diameter of ·0394″ and ·0343″ respectively. If the Laplacian law of density were to hold good, and if the surface density were zero, we should have, ϵ = ·00001596, or ϵ' = ·00001390, which correspond to differences of ·0307″ and ·0267″ respectively.

Mr. Christie informs me that the probable error in the de-

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termination of the Sun's apparent diameter is not less than 0·1″, and it appears that the observed difference of diameters is also 0·1″.

May we not conclude that the difference of the apparent diameters is probably less than ·04″, but perhaps greater than ·03″ ?

Note on the Relative Space-penetrating Power of the Pulkowa 15-inch Refractor and Mr. Lassell's 4-foot Reflector. By M. Otto Struve.

In his paper "On the Relative Power of Achromatic and Reflecting Telescopes" (*Monthly Notices*, vol. xxxvi. pp. 305–309) Dr. Robinson makes the following statement:—

"2. Otto Struve *thought* that the Pulkowa Achromatic of 15-inches was equal to Lassell's 24-inch Newtonian (not his 4-feet, as supposed by M. Radau): nothing definite can be built on this."

I feel sure, if Dr. Robinson had read my paper, "Ueber das von Herrn W. Lassell in Malta aufgestellte Spiegelteleskop," published in the beginning of 1864 in the *Bulletin de l'Académie de St.-Pétersbourg*, he would have considerably modified his words, and perhaps also his views. In fact, M. Radau has been quite correct in his statement. I wrote the above-mentioned paper immediately after having visited my honoured friend Mr. Lassell at Malta. Together with some other results derived from practical experience, I have given there, *in extenso*, the comparison of the ultima visibilia in the nebula of *Orion*, observed at Pulkowa by Dr. Winnecke, simultaneously with me, at Malta. The result of this comparison is expressed in the following terms:—"The preceding comparison of almost simultaneous observations made at Malta and Pulkowa proves evidently that the space-penetrating power of Lassell's new (4-feet) instrument can hardly be estimated superior to that of ours (the Pulkowa 15-inch) refractor; especially if we consider that at Pulkowa the nebula of *Orion* has been observed at a height of only 25°, while at Malta the observations were made at the height of 49°."

I beg leave to add that in 1863, as a great many comparisons made about that time have proved, my eye was still quite of the same strength with that of Dr. Winnecke.

Pulkowa, 1876, November.

On the Position of the Point of Maximum Brightness on Venus. By E. Neison, Esq.

Supposing *Venus* to reflect the solar rays from a dead or unpolished surface, the intensity of illumination of the surface at any point P will be proportional to the cosine of the zenith

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distance of the Sun (=z) at that point. Then from a known optical principle, the apparent brightness of the surface at P as seen from the Earth will be proportional to the real illumination. Consequently, the apparent brightness B of any point on *Venus* as seen from the Earth will be

$$B = A \cos z.$$

The point where the apparent brightness is greatest will be therefore that where the Sun is in the zenith.

Consequently, when *Venus* is crescent, or less than one half of the illuminated hemisphere of *Venus* is visible, the limb of the planet will be the brightest portion. This is what the observations of Capt. Noble (*Monthly Notices*, vol. xxxv. p. 350) have already indicated. When, however, the planet is gibbous, so that more than half the illuminated hemisphere can be seen, then the point of maximum illumination will be within the limb. Under these conditions, in fact, the region of maximum brightness will be an ellipse of great eccentricity.

This is in accord with the observations of Mr. Christie, communicated to the Society in November 1876.

These two series of observations are not therefore, discordant, as might be supposed, and neither confirm the hypothesis that the solar rays are specularly reflected from the surface of *Venus*.

Note on the Gradation of Light on the Disk of Venus.

By W. H. M. Christie, Esq.

Some months ago Mr. Brett pointed out that there was a gradation of brightness towards the limb of *Venus* as well as, in a more marked degree, towards the terminator, and he considered that this was due to specular reflexion modified by large atmospheric diffusion. As *Venus* was then becoming crescent-shaped, and therefore unfavourably situated for showing any effect of specular reflexion, I had no opportunity of testing the point till after inferior conjunction. When the planet became gibbous again, I examined the disk on several occasions in the forenoon with the direct-vision polarising eyepiece, described in the *Monthly Notices* for last January, applied to the Great Equatoreal of the Greenwich Observatory, and was thus enabled to reduce the brightness very gradually to the point of total disappearance. On October 12 the disk was reduced, on turning the Nicol prism, to an oblong patch, the edge of which was distant about one-sixth of the diameter of *Venus* from the limb, special attention being directed to this point. Afterwards, on November 28 and December 6, under more favourable circumstances, four distinct phases were remarked, corresponding to different readings of the position-circle attached to the Nicol, and indicating four different degrees of brightness:

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(*a*) At the first phase the limb was just beginning to fade, the disk being then gibbous, though a small portion near the terminator had, as far as I could judge, already disappeared.

(*b*) The next phase was an oblong patch, from two-thirds to three-quarters of the planet's diameter in length, in the direction of the line of cusps, and about one-third as broad as it was long.

(*c*) On turning the Nicol further, the ends of this patch disappeared, and a nebulous spot, about one-third of the diameter of *Venus*, and condensed towards the centre, was seen.

(*d*) Finally, just before total disappearance, the disk was reduced to a nearly stellar point from one-sixth to one-tenth of the original diameter, and surrounded by an extremely faint haze, which was occasionally invisible, leaving nothing but a minute point of light to be seen. The appearance was exactly that of the nucleus of a small comet, or of a nebulous star. By the help of a pointer in the field of view, the position of this stellar point was found to be about the middle of the visible disk.

From several sets of closely accordant readings of the position-circle, taken with the eyepiece in various positions, the angles for the Nicol measured from the position for which its plane of polarisation is perpendicular, to the plane of reflexion in the eyepiece, were found as follows for the respective phases :—

(*a*) 30° (*b*) 24° (*c*) 13° (*d*) 11°

Since the intensities of light transmitted by the Nicol are as the squares of the sines of the above angles, we get, taking the faintest portion of phase *a* as standard:—brightness of $b=1{\cdot}5$, of $c=4{\cdot}8$, of $d=7{\cdot}0$. So that it would appear that the central portion of the disk is about seven times as bright as the part near the limb. It may be thought strange that so great a difference in brightness should not be more noticeable, but it would seem that a highly-trained eye is required to detect a gradation in bright objects, though when the brightness is reduced nearly to the vanishing point, there is no difficulty in seeing it. In the polarising eyepiece the light is reduced in the first instance to about 1-3000th part by the three reflexions, and with the Nicol at the reading for phase *d* it is further reduced to one-thirtieth of this amount, or 1-90,000th of the original brightness. Though the extinction method of photometry is liable to large error from variation in the sensitiveness of the eye, it may be trusted for comparative results, where, as in this case, there is an extremely faint background of scattered daylight, which gives a sort of standard for comparison.

Whatever uncertainty there may be in the actual values found for the brightness, there can, I think, be no doubt of the fact of a considerable gradation of light from a central, or nearly central spot; and it seems difficult to explain this on any other hypothesis than that of specular reflexion modified by atmospheric diffusion.

1876, *December* 7.

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On Spheroidal Trigonometry. By Prof. Cayley.

The fundamental formulæ of Spheroidal Trigonometry are those which belong to a right-angled triangle PSS_0, where P is the pole, PS, PS_0 arcs of meridian, and SS_0 a geodesic line cutting the meridian PS at a given angle, and the meridian PS_0 at right angles. We consider a spherical triangle PSS_0,

Sides	PS,	PS_0,	$SS_0 = \gamma$,	γ_0,	s,
Angles	S_0,	S,	P $= 90°$,	θ,	l,

where γ is the reduced colatitude of the point S on the spheroid (and thence also γ_0 the reduced colatitude of S_0) and θ the azimuth of the geodesic SS_0, or angle at which this cuts the meridian SP; and then if S be the length of the geodesic SS_0 measured as a circular arc, radius = Earth's equatoreal radius, and L be the angle SPS_0, S, L differ from the corresponding spherical quantities s, l by terms involving the excentricity of the spheroid, viz. calling this e and writing

$$k = \frac{e \cos \gamma_0}{\sqrt{1 - e^2 \sin^2 \gamma_0}},$$

then (see Hansen's *Geodätische Untersuchungen, Abh. der K. Sächs. Gesell.*, t. viii. (1865) pp. 15 and 23, but using the foregoing notation) we have, to terms of the sixth order in e,

$$\begin{aligned} \frac{S}{\sqrt{1-e^2}} = & \left(1 + \frac{1}{4}k^2 + \frac{13}{64}k^4 + \frac{45}{256}k^6\right) s \\ & + \left(\frac{1}{8}k^2 + \frac{3}{32}k^4 + \frac{79}{1024}k^6\right) \sin 2s \\ & + \left(\frac{1}{256}k^4 + \frac{5}{1024}k^6\right) \sin 4s \\ & + \frac{1}{3072}k^6 \sin 6s; \end{aligned}$$

and

$$\begin{aligned} L = & \; l - \frac{1}{2}e^2 \sin \gamma_0 \left\{ \left(1 - \frac{1}{8}k^2 + \frac{1}{4}e^2 - \frac{5}{64}k^4 + \frac{1}{8}e^4\right) s \right. \\ & - \left(\frac{1}{16}k^2 + \frac{1}{32}k^4\right) \sin 2s \\ & \left. + \frac{1}{256}k^4 \sin 4s \right\}, \end{aligned}$$

which are the formulæ in question.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. *January* 12, 1877. No. 3.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Robert John Baillie, Esq., 10 Bolton Place, Carlisle;
H. Vere Barclay, Esq,, 6 Disraeli Terrace, Putney;
Rev. Daniel Dutton, Sandbach, Cheshire;
Samuel Heywood, Esq., 171 Stanhope Street, Hampstead Road;
Louis Stromeyer Little, Esq., M.D., B.A., 18 Park Street, Grosvenor Square;
Robert Pearce, Esq., Church Court Chambers, Old Jewry;
Commander William James Lloyd Wharton, H.M. Surveying Ship "Fawn;"
Jesse Young, Esq., Stibbington House, Wantsford,

were balloted for and duly elected Fellows of the Society.

Theory of the Horizontal Photoheliograph, including its application to the determination of the Solar Parallax by means of Transits of Venus. By Professor William Harkness, U. S. Navy. (Abstract.)

(*Communicated by the Astronomer Royal.*)

The term "Horizontal Photoheliograph" is used to designate that form of photoheliograph which, it is believed, was first employed by the late Professor Winlock, and which consists essentially of a fixed telescope, whose optical axis is accurately horizontal and in the meridian, and whose objective is directed towards the same side of the zenith as the elevated pole; the Sun's rays being reflected into the telescope by a suitable heliostat. The sensitive plate for the reception of the photographic image is, of course, situated at the chemical focus of the telescope,

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the plane of the plate being perpendicular to, and its centre coinciding with, the optical axis of the telescope.

The heliostat mirror consists of a piece of highly polished (but unsilvered) glass, whose two surfaces make an angle of about sixty minutes with each other. The front surface is worked as truly plane as possible, and serves to reflect the solar rays through the object-glass to the photographic plate. In working the back surface, no particular pains are taken; and, on account of its inclination to the front surface, any light reflected from it is thrown entirely away from the photographic plate. The object-glass is corrected for the chemical, and not for the visual rays. The distance between the object-glass and mirror is made as small as possible, consistently with keeping the latter clear of the shadow of the former. The sensitive surface of the photographic plate faces the object-glass, while the rays from the Sun are reflected by the mirror through the object-glass, and after traversing the reticule, they form an image upon the photographic plate.

The reticule consists of a system of squares, formed by the intersection of two systems of very fine straight lines, which are drawn upon one side of, and respectively parallel to, the edges of a thin square plate of plano-parallel glass. In each of these linear systems the number of lines is odd, and the middle line is drawn through the centre of the plate. This reticule is fixed with its ruled surface toward, parallel to, and two or three millemeters distant from, the sensitive surface of the photographic plate. Moreover, one of the two systems of lines is set as nearly as possible vertical, and its inclination is accurately determined; and, to render assurance doubly sure, a plumb-line, consisting of a silver wire about 0·05 of a millemeter in diameter, is suspended between the reticule and the photographic plate, in such a position that it may hang freely, and at the same time be very nearly in the vertical plane passing through the centres of the reticule and object-glass. As the light from the object-glass traverses the reticule before it reaches the photographic plate, the shadow, both of the reticule and of plumb-line, is impressed upon every picture taken with the apparatus; and thus three different ends are gained: First, by comparing the squares of the reticule with the corresponding ones upon the picture, everything relating to the shrinkage of the collodion can be determined; secondly, the impression of the plumb-line, and also that of the vertical lines, furnishes upon each picture a fixed direction from which to measure angles of position; and, thirdly, the intersection of the middle vertical with the middle horizontal line furnishes a fixed point, which in the paper is designated as the centre of the plate. To determine the zenith distance and azimuth of this point, it is necessary to measure the zenith distance and azimuth of the corresponding point of the reticule, as seen from the second principal point of the object-glass. For that purpose, the mirror is temporarily removed, and a

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transit instrument is set up in front of the object-glass in prolongation of its axis. The object-glass thus becomes a collimator to the transit instrument, through the eyepiece of which the lines of the reticule may be observed as if they were at an infinite distance. It should be remarked, however, that as the reticule is slightly inside the visual focus of the object-glass, it is not generally possible to obtain perfectly distinct vision of its lines and of the wires of the transit at the same time. This difficulty is obviated by marking the intersection of the middle vertical and middle horizontal lines of the reticule in such a distinct manner, that the slight maladjustment of focus does not prevent it from being seen. Then, by means of the transit, the reticule is adjusted so that the point in question is very approximately in the meridian, and at a zenith distance of ninety degrees. Finally, the exact azimuth and zenith distance of the point are measured.

The remainder of Professor Harkness's paper, which will probably be given *in extenso* in the *Memoirs* of the Society, is occupied with a full and detailed explanation, with diagrams, of the principle of the instrument, and of the methods of measurement of the photographs.

Micrometrical Measures of Double Stars. By George Knott. (Abstract).*

I have the honour of presenting to the Royal Astronomical Society a short series of Micrometrical Measures of Double Stars, taken between the years 1860 and 1873, at my former residence, Woodcroft, Cuckfield.

The Observatory, detached at some little distance from the house, and commanding a good horizon view, stood at an elevation above the sea level of about 370 feet, and in the approximate position, latitude 51° 0′ 41″ North, longitude $0^h\ 0^m\ 34^s$ West.

The Equatoreal has an object-glass of $7\frac{1}{3}$-inches clear aperture and $110\frac{1}{2}$-inches focal length, by Messrs. Alvan Clark and Sons of Boston, U.S.A., and is a fine specimen of the makers' skill. It was formerly in the possession of the Rev. W. R. Dawes.

The filar, or parallel-wire, micrometer, employed in the following measures, was made for me by the late Mr. Dollond. It has a position-circle of $3\frac{1}{2}$-inches diameter, reading, by two verniers, to tenths of a degree, and the angle of position is taken by placing the two stars under observation centrally parallel between two thick wires, about 13″ apart. At right angles to the position-wires are the webs for distance-measures, of which two, one

* The Paper will probably appear *in extenso* in the *Memoirs* of the Society.—Ed.

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fine and the other coarse (the latter for measures of faint objects, but rarely used), are carried by each screw.

The screw-heads, divided to 100 parts, are of nearly two inches diameter, and are fitted with bolts, so that either web may be fixed as zero-wire, while the other is used in making the measures. There is a battery of seven eye-pieces, with magnifying powers from 115 to 515, and, by the use of an achromatic concave Barlow-lens, the magnifying power may be increased in the proportion of about 2·25 to 1. The micrometer is also fitted with a convenient slipping-piece. The value of one revolution of the screw is 18″·2949, and with the Barlow-lens, 8″·0765.

In reducing the observations, the arithmetical mean is taken as the mean for the night. To each individual measure a number is assigned (1–9) expressive of its estimated worth, and the sum of these numbers is taken as the weight of the set, which is thus a function of the number of observations and of the estimated value of each measure. In forming the "Mean results" (or mean of several nights' measures), this number is introduced as the *combination weight.*

Being interested in the observation of Variable Stars, I found it convenient to adopt Mr. Pogson's standard scale, or Argelander's scale extended to the lower magnitudes by the adopted light-ratio 2·512. (*Monthly Notices*, vol. xvii. p. 15.) The numbers expressing the magnitudes will be found therefore to lie generally between those of Σ on the one hand, and that of H. and Sm. on the other, the difference being more marked in the lower magnitudes. Although, for convenience, the magnitudes are expressed decimally, they must not be regarded as making any pretensions to very close accuracy.

Cuckfield,
1877, *January* 11.

On the Orbit of α Centauri. By J. R. Hind.

Having been lately favoured by Lord Lindsay with the results of two sets of measures of the angle of position of *α Centauri* made with the heliometer at the Mauritius in November 1874, during his Lordship's expedition for the observation of the transit of *Venus*, I have attempted a further approximation to the elements of this most interesting binary.

I employed the last orbit by Mr. Eyre B. Powell, of Madras, in the formation of equations of condition, for the epochs of the most reliable mean results, depending on the measures of Sir John Herschel, Captain Jacob, Mr. Powell, and Lord Lindsay, at the same time admitting the angle for 1752·2 given by Lacaille's Right

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Ascension and Declination. The elements obtained by the solution of the equations are as follow :—

Peri-astron passage	1874·85
	° ′
Node	21 48·0
Node to peri-astron on orbit	59 32·1
Inclination	82 18·4
Angle of eccentricity	41 51·5
or e = 0·6673	
	″
Semi-axis major	21·797
	yrs.
Period of revolution	85·042

The following is the comparison with observations :—

		Position (C−O).	Distance (C−O).	
		°	″	
Lacaille	1752·2	−0·8	−4·7	
Brisbane	1825·0	−4·0	+0·2	
Johnson	1830·0	−2·1	+0·2	
Cape	1833·0	−2·9	+0·1	
Herschel	1836·00	−2·6	...	
„	1836·06	...	−0·23	
Cape	1840·0	+3·9	−3·22	
Jacob	1846·75	−2·7	−1·07	
„	1848·02	−2·6	−0·28	
„	1850·83	−2·1	−0·32	
„	1852·23	−2·7	−0·15	
„	1856·27	+1·6	−0·16	
„	1857·15	+1·0	+0·03	
Powell	1859·38	+0·9	−0·98	
„	1860·11	+1·0	−0·18	
„	1861·05	+1·0	+0·06	
„	1862·21	−0·7	+0·11	
„	1863·08	−0·7	+0·29	
„	1863·11	−4·9	−0·34	Position preferred by Powell to last
„	1870·10	−3·0	+0·23	
Lindsay	1874·85	+0·4	...	

It will be remarked that Lord Lindsay's measures fall exactly at the computed time of nearest approach of the component stars in the real orbit. Probably a somewhat closer

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representation of the observed angles and distances might be obtained by repeating the process upon which the above elements were deduced, but I defer any further computation in the hope of soon receiving measures made after the passage of the peri-astron.

Lord Lindsay's epoch, as used above, is,

1874·85 34°·17

If, for the annual parallax, a mean of Henderson's value, as corrected by Peters, and that of Moesta, be taken, giving 0″·928, we find the mass of this system = 1·79 × ⊙'s mass, and for the semi-axis major of the orbit 23·49.

Ephemeris for Determining the Positions of the Satellites of Uranus, 1877.

By A. Marth, Esq.

(*Communicated by A. C. Ranyard, Esq.*)

Greenw. Noon. 1877.	*p*	Ariel.		Umbriel.		Titania.		Oberon.	
		log *a*	log *b*	log *a*	log *b*	log *a*	log *b*	log *a*	log *b*
Jan. 25	10·48	1·1811	0·7569	1·3251	0·9009	1·5400	1·1158	1·6662	1·2420
30	10·41	·1817	·7613	·3257	·9053	·5406	·1204	·6668	·2464
Feb. 4	10·34	·1821	·7656	·3261	·9096	·5410	·1245	·6672	·2507
9	10·27	·1823	·7697	·3263	·9137	·5412	·1286	·6674	·2548
14	10·21	·1823	·7736	·3263	·9176	·5412	·1325	·6674	·2587
19	10·14	·1822	·7772	·3262	·9212	·5411	·1361	·6673	·2623
24	10·07	·1818	·7806	·3258	·9246	·5407	·1395	·6669	·2657
Mar. 1	10·01	·1812	·7836	·3252	·9276	·5401	·1425	·6663	·2687
6	9·95	·1804	·7862	·3244	·9302	·5393	·1451	·6655	·2713
11	9·89	·1795	·7885	·3235	·9325	·5384	·1474	·6646	·2736
16	9·83	·1784	·7903	·3224	·9343	·5373	·1492	·6635	·2754
21	9·78	·1772	·7918	·3212	·9358	·5361	·1507	·6623	·2769
26	9·73	·1758	·7928	·3198	·9368	·5347	·1517	·6609	·2779
31	9·69	·1743	·7934	·3183	·9374	·5332	·1523	·6594	·2785
Apr. 5	9·66	·1727	·7935	·3167	·9375	·5316	·1524	·6578	·2786
10	9·63	·1710	·7932	·3150	·9372	·5299	·1521	·6561	·2783
15	9·61	·1692	·7925	·3132	·9365	·5281	·1514	·6543	·2776
20	9·60	·1673	·7913	·3113	·9353	·5262	·1502	·6524	·2764
25	9·59	·1654	·7896	·3094	·9337	·5243	·1486	·6505	·2748
30	9·59	·1635	·7878	·3075	·9318	·5224	·1467	·6486	·2729
May 5	9·60	1·1615	0·7854	1·3055	0·9294	1·5204	1·1443	1·6466	1·2705

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a and b are the major and minor semi-axes of the apparent orbits of the satellites, expressed in seconds of arc; p_o is the position-angle of the major axes. The longitudes ω of the satellites in their orbits, reckoned from the points of their greatest northern elongations, are the following:—

Greenwich, Noon.	Ariel. ω	diff.	Umbriel. ω	diff.	Titania. ω	diff.	Oberon. ω	diff.
	°	°	°	°	°	°	°	°
Jan. 25	168·28		330·37		19·65		248·04	
		714·16		434·32		206·72		133·67
30	162·44		44·69		226·37		21·71	
		·15		·31		·72		·66
Feb. 4	156·59		119·00		73·09		155·37	
		·15		·31		·72		·66
9	150·74		193·31		279·81		289·03	
		·14		·31		·72		·66
14	144·88		267·62		126·53		62·69	
		·13		·30		·72		·66
19	139·01		341·92		333·25		196·35	
		·13		·30		·72		·66
24	133·14		56·22		179·97		320·01	
		·12		·30		·72		·66
Mar. 1	127·26		130·52		26·69		103·67	
		·12		·30		·71		·66
6	121·38		204·82		233·40		237·33	
		·12		·29		·72		·66
11	115·50		279·11		80·12		10·99	
		·12		·30		·72		·66
16	109·62		353·41		286·84		144·65	
		·11		·29		·72		·67
21	103·73		67·70		133·56		278·32	
		·10		·30		·72		·66
26	97·83		142·00		340·28		51·98	
		·11		·29		·72		·67
31	91·94		216·29		187·00		185·65	
		·11		·30		·73		.67
Apr. 5	86·05		290·59		33·73		319·32	
		·11		·29		·72		·68
10	80·16		4·88		240·45		93·00	
		·10		·30		·73		·67
15	74·26		79·18		87·18		226·67	
		·11		·30		·73		·68
20	68·37		153·48		293·91		0·35	
		·11		·30		·74		·69
25	62·48		227·78		140·65		134·04	
		·11		·31		·74		·68
30	56·59		302·09		347·39		267·72	
		714·12		434·30		206·74		133·69
May 5	50·71		16·39		194·13		41·41	

These values must be interpolated for the times for which the position of the Satellites are required. The angles of position p and distances s are then found by means of the equations—

$$s \sin (p_o - p) = b \sin \omega.$$
$$s \cos (p_o - p) = a \cos \omega.$$

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The interpolation of the values of ω may be facilitated by the following tables, which give the motion of ω for every even hour of the five days' interval:—

Ariel, diff. = 714°·12.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	142·82	285·65	68·47	211·30
2	11·90	154·73	297·55	80·37	223·20
4	23·80	166·63	309·45	92·28	235·10
6	35·71	178·53	321·35	104·18	247·00
8	47·61	190·43	333·25	116·08	258·90
10	59·51	202·33	345·16	127·98	270·81
12	71·41	214·24	357·06	139·88	282·71
14	83·31	226·14	8·96	151·79	294·61
16	95·22	238·04	20·86	163·69	306·51
18	107·12	249·94	32·77	175·59	318·41
20	119·02	261·84	44·67	187·49	330·32
22	130·92	273·75	56·57	199·39	342·22
24	142·82	285·65	68·47	211·30	354·12

Umbriel, diff. = 434°·28.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	86·86	173·71	260·57	347·42
2	7·24	94·09	180·95	267·81	354·66
4	14·48	101·33	188·19	275·04	1·90
6	21·71	108·57	195·43	282·28	9·14
8	28·95	115·81	202·66	289·52	16·38
10	36·19	123·05	209·90	296·76	23·61
12	43·43	130·28	217·14	304·00	30·85
14	50·67	137·52	224·38	311·23	38·09
16	57·90	144·76	231·62	318·47	45·33
18	65·14	152·00	238·85	325·71	52·57
20	72·38	159·24	246·09	332·95	59·80
22	79·62	166·47	253·33	340·19	67·04
24	86·86	173·71	260·57	347·42	74·28

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Titania, diff. = 206°·70.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	41·34	82·68	124·02	165·36
2	3·45	44·79	86·13	127·47	168·81
4	6·89	48·23	89·57	130·91	172·25
6	10·34	51·68	93·02	134·36	175·70
8	13·78	55·12	96·46	137·80	179·14
10	17·23	58·57	99·91	141·25	182·59
12	20·67	62·01	103·35	144·69	186·03
14	24·12	65·46	106·80	148·14	189·48
16	27·56	68·90	110·24	151·58	192·92
18	31·01	72·35	113·69	155·03	196·37
20	34·45	75·79	117·13	158·47	199·81
22	37·90	79·24	120·58	161·92	203·26
24	41·34	82·68	124·02	165·36	206·70

Oberon, diff. = 133°·68.

h	0d	1d	2d	3d	4d
	°	°	°	°	°
0	0·00	26·74	53·47	80·21	106·94
2	2·23	28·96	55·70	82·44	109·17
4	4·46	31·19	57·93	84·66	111·40
6	6·68	33·42	60·16	86·89	113·63
8	8·91	35·65	62·38	89·12	115·86
10	11·14	37·88	64·61	91·35	118·08
12	13·37	40·10	66·84	93·58	120·31
14	15·60	42·33	69·07	95·80	122·54
16	17·82	44·56	71·30	98·03	124·77
18	20·05	46·79	73·52	100·26	127·00
20	22·28	49·02	75·75	102·49	129·22
22	24·51	51·24	77·98	104·72	131·45
24	26·74	53·47	80·21	106·94	133·68

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On the Conjunction of Venus and λ Geminorum.

By John I. Plummer.

In a late number of the *Monthly Notices* (vol. xxxvi. p. 340) Mr. Dunkin has called attention to the proposal of Dr. Krüger, that astronomers in either hemisphere should avail themselves of the near approach of *Venus* to the bright star λ *Geminorum*, at a time when the planet was but little distant from the Earth, with the view of determining the solar parallax. It may, therefore, be of interest to the Fellows of the Society to record the degree of success that has attended the observations at the Orwell Observatory. The plan which it was proposed to pursue on the occasion, was to measure differences of declination of the planet and star, commencing as soon as *Venus* had attained an altitude of 20°, to be continued so long as circumstances would permit, since with the large aperture at my command (10·7 inches), no difficulty would be experienced in following up the observations to the time of actual conjunction in Right Ascension. Five comparisons of each limb of the planet with the star were to be made with a parallel-wire micrometer (power 315) alternately, and it was confidently expected that the probable error of the mean of each set would not exceed $\frac{1}{10}$th of a second of arc. Such a series would have been useful if corresponding observations had been made at any position in the southern hemisphere, and failing a preconcerted arrangement with a southern station, was the most satisfactory scheme that suggested itself to my mind.

Unhappily it was discovered on the morning of August 18, that the definition of the planet and star was not sufficiently sharp for the desired degree of accuracy to be ensured, and was at times so indifferent that I was doubtful whether measures avowedly so delicate ought not to be discontinued. They were, however, persevered in until $18^h\ 46^m$ G.M.T., when cirrus cloud overspread the sky, obliterating both objects for several hours. By this time 10 sets of 5 comparisons each had been obtained, and, although these may not fully serve the end for which they were undertaken, they quite unexpectedly throw light upon a question to which I have always attached some interest.

The following is a comparison of the observations with the Ephemeris of the *Nautical Almanac*, which has been made in order to test the reliability of the individual sets, assuming, for the purposes of reduction, the solar parallax equal to 8″·90, and the apparent declination of the star +16°45′51″·84. It should be remarked that the north limb of the planet was full, and that the correction for defective illumination of the south limb was so small as to be quite insensible.

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Venus, N.L. — λ *Geminorum*.

Set.	Greenwich Mean Time of Observation. h m s		Uncorrected Difference of N.P.D. ′ ″	Assumed Semidiameter of *Venus*. ″	Differential Refraction Correction. ″	Correction for Parallax.	Observed N.P.D. of *Venus*—Calculated N.P.D.	Weight.
1	16 27 15·7	(*a*)	+1 46·587	+20·048	+0·116	−14·330	−0·315	4
3	16 56 40·5		+1 43·562	+20·042	+0·086	−13·891	+0·039	3
5	17 15 4·9	(*b*)	+1 42·144	+20·037	+0·074	−13·625	+0·729	2
7	17 53 31·4		+1 38·161	+20·029	+0·058	−13·111	+1·115	2
9	18 21 56·6		+1 34·259	+20·023	+0·049	−12·778	+0·396	3

Venus, S.L. — λ *Geminorum*.

2	16 39 45·2		+2 26·611	−20·045	+0·141	−14·141	+1·094	3
4	17 5 6·4		+2 22·991	−20·040	+0·111	−13·771	+0·382	3
6	17 30 31·9		+2 19·915	−20·034	+0·092	−13·413	+0·219	2
8	18 9 16·3	(*c*)	+2 15·360	−20·025	+0·074	−12·913	+0·062	4
10	18 39 56·4	(*d*)	+2 10·274	−20·019	+0·065	−12·586	−1·611	1

Remarks.—(*a*) Sky quite clear and images fairly steady.—(*b*) Shortly after sunrise the definition of the planet became gradually worse, and the star faint, large, and trembling.—(*c*) Definition of *Venus* much improved, and the star which had nearly disappeared is now smaller and more easily seen.—(*d*) Images bad again: cirrus cloud completely hid the star after four bisections, which were all that could be obtained with difficulty for this set. It is from the consideration of these remarks alone that weights have been assigned in the last column.

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In comparing the observations with the Ephemeris we may obviously employ whatever value of the planet's semidiameter we please, and I have, therefore, adopted that which best satisfies the observations themselves, namely 8″·698 at mean distance. This is very slightly larger than that determined by myself with the double-image micrometer in 1873 (8″·661), but is less than the well-known determination of Mr. Maine (8″·775). In spite of the unsatisfactory state of the sky, an analysis of the individual bisections shows that the probable error of a single set of observations does certainly not exceed 0″·21, and it was, therefore, very disappointing to deduce the marked discordances that occur in the 7th column. If, however, we assume that the apparent semidiameter of the planet, owing to irradiation, did not remain constant before and after sunrise, but diminished in proportion as the neighbouring sky became more and more illuminated, an explanation of these anomalous results is possible, and their true significance will be apparent when exhibited in the following form :—

			Weight as before.	Approx. G.M.T. of Observation. h	m	Group.
Mean excess of planet's observed N.P.D. over that of Ephemeris, giving weights as above	...	+0·268				
Apparent excess of observed semidiameter over that assumed in the previous reductions.	Set 1	+0·583	4	16	27	1
	„ 2	+0·806	3	16	40	
	„ 3	+0·229	3	16	57	2
	„ 4	+0·114	3	17	5	
	„ 5	−0·461	2	17	15	
	„ 6	−0·049	2	17	31	3
	„ 7	−0·847	2	17	54	
	„ 8	−0·206	4	18	9	
	„ 9	−0·128	3	18	22	
	„ 10	−1·879	1	18	40	
Greenwich Mean Time of Sunrise at Orwell Park			...	16	44	

Not only do these figures show a gradual decrease of the apparent semidiameter, and a more sudden diminution at the moment of sunrise, but dividing them into three groups and taking the mean of each we shall arrive at a pretty fair approximation to the amount of variation due to the several states of illumination of the sky. Thus the mean of sets 1 and 2 shows that before sunrise the contacts were made too *remote*, and the measured semidiameter was consequently too great, by the quantity 0″·679 (Wt. 7). The next three sets, which were taken when the Sun was very low, yield an average of only 0″·013 (Wt. 8), as the excess of the measured semidiameter over the assumed value. The mean of the sets 6–9, observed after the Sun had fairly freed itself from the haze of the horizon, shows

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the contacts to have been made too *close* by the quantity 0″·273 (Wt. 11), the observed semidiameter being too small by that amount. The final result shows unmistakeably that the effect of the cloud through which this set was observed had been to cut off the sharp cusp altogether, and to reduce the planet more or less to the oblong figure artificially produced by Mr. Christie.

In the paper to which I have already referred (*Monthly Notices*, vol. xxxiii. p. 562), I have stated that there can be little doubt that the amount of irradiation of the disk of *Venus* varies from day to day with the transparency of the atmosphere. I have only to add, that the preceding observations prove beyond question that such changes occur at much smaller intervals, and that near the hour of sunrise or sunset are of such magnitude as to require careful elimination in all observations of accuracy. Finally, we may conclude that for the determination of solar parallax by the method suggested by MM. Krüger and Dunkin, each limb of the planet will require to be observed simultaneously or nearly so, in order to evade this peculiarity; and that had this been provided for at both northern and southern stations a valuable result would most probably have been obtained.

Orwell Park Observatory,
1876, *December* 12.

Observations of Shooting Stars, April to December, 1876.

By W. F. Denning, Esq., F.M.S.

(*Communicated by the Rev. R. Main, M.A., F.R.S.*)

The following list of 51 radiant-points were deduced from the paths of 766 shooting stars observed and registered at Bristol during the nine months, April to December, 1876. About 1,050 were seen altogether within this period, but some of them (including a number of Perseids, Geminids, etc.) were not recorded, as their radiants had already been indicated with sufficient accuracy from other paths; and the remainder were not well seen, and accordingly had to be rejected. Previously to October my observations were made irregularly, and not often continued for long periods, but during the last three months of the year the sky was watched on every fine night for several hours, generally before midnight. This will account for my having seen many more meteors in the autumnal months than in the spring and summer. In October, November, and December, during watches amounting in the aggregate to 69½ hours, 532 meteors were seen, and 447 of them registered. Of the total number observed, 322 were noted in 49 hours' watching before midnight, and 210 of them in 20½ hours after midnight (chiefly between 3 and 6 A.M.), so that the rate of frequency A.M. greatly exceeded that P.M., and this was especially marked in November. During the preceding months I did very little work

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A.M., and have no data to make the same comparison. The chief showers of the period under review were the Perseids (August 10), the Geminids (December 12), the Cassiopeids (July–August), the Draconids (July–August), the Muscids (October 15), the Taurids I. (November 8), the Taurids II. (December 6), the Aurigids (November and December 13), the Leonids minor (November 25–28), etc. About 40 of the positions included in the list are redeterminations of showers already known or suspected, and in regard to the latter these confirmations will be useful. The remainder appear to be new, and were principally observed in the mornings of November and December, and one of them (a bright and somewhat active display of slow meteors) was seen in the evenings—notably on December 6, when it supplied nearly one-half of the visible shooting stars, as did the Geminids on the night of December 12. A feeble and very late return of the Leonids was observed on the nights of November 19–20 (or A.M. 20–21), but cloudy weather had prevented a look-out on the few preceding nights. From the same cause the Lyraids (April 19–20) entirely eluded me. The Orionids (October 17–19) appear this year to have been but feebly shown, and I saw few of them; but there was much cloudy weather at about that time also, wholly preventing a watch on several nights, and thus the maximum of the shower may have escaped me, as in other cases, for from the results of a single year's observation little can be expected to be done in determining durations and intensities of meteor showers, and some of the brightest and most transient will pass altogether unseen. It is only by observation extending over many successive years that so much has already been learned of these features in regard to many of the leading showers. The dates I have given in the list are those within which shooting stars continued to diverge from the radiants mentioned, and do not pretend to show the absolute periods over which the showers extend, though in some cases this is very near the truth. The list does not include some extremely feeble or suspected radiants, supplying 3, 4, or 5 meteors each, which I have held over and will endeavour to confirm another year. 660 shooting stars are included in the 51 radiant points actually specified, which comprised a large proportion of small meteors, the relative magnitude of the aggregate number registered during the nine months being:—

>1st mag. and = ♃ or ♀	=1st mag.	=2nd mag.	=3rd mag.	=4th mag.	=5th mag.	and—total.
29	55	150	182	234	116	=766

Many fine meteors (including several fireballs) were seen in August (chiefly Perseids), and in December (chiefly Geminids), but in the spring months and in October they were generally very small, and the great majority 3rd–4th mag. In the list I have given the probable number of shooting stars recorded as belonging to each radiant, as this is an important detail, not only as showing the intensity of the shower, but also the value of the position deduced. I have added a column, indicating the

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observed specialities of the meteors of each shower, though, obviously, not much can be done in this respect from a single year's work, but it may lead to something more definite and satisfactory being attempted and followed out in the same direction in future years. The descriptions are not by any means to be held as conclusive (for the materials were often scanty, and sometimes uncertain), but as applying only to those members of the different systems that really came under observation, and, except in regard to the more active showers, they may not have afforded a fair sample of the whole. Moreover, the appearance of a meteor is dependent in a great measure upon the position of the radiant point with respect to the apex of the Earth's way. Again, when near the radiant the path is much foreshortened, and the apparent velocity much below the average of the same shower, and *vice versâ*. A white meteor on the horizon will often look ruddy, etc., but, notwithstanding these difficulties, the special features of certain showers are strongly marked and distinct from those of neighbouring ones, and it is an important element to consider, inasmuch as it frequently occurs that contemporary radiants lie near together (or in the same backward prolongation of a meteor's track), and it is sometimes impossible to accord the true focus, unless such details are noted and taken into the account. In some systems these specialities of appearance or motion are strikingly evident, and serve (almost as unerringly as direction of path) to indicate the real centres of emanation. Thus, as instances of extreme velocity, there are the Polarids (September–October), Gemellids (October–November), Draconids, etc.; and as samples of slow motion, the Aquilids (July–August), the Piscids (September–October), the Geminids (December), etc. In the same column I have also given in a few instances the dates of observed maximum or greatest activity.

I have subjoined a list of the observed paths of 85 bright shooting stars recorded during the nine months. These will be useful to compare with the observations of others who may have seen some of them and can afford materials for the calculation of the heights, etc. The magnitudes given are intended to show the *maximum* brilliancy, and the comparisons are with planets and stars of the 1st mag. I have endeavoured to give the *direction* of the paths with as much accuracy as possible, as this is important in the finding of the true radiants, a column of which I have affixed, indicating them. Some details of motion and appearance are also added, but these are somewhat incomplete, especially those relating to colour. Generally, however, I found the slow meteors more or less ruddy, while the rapid ones appeared almost invariably white. Several fine meteors, apparently from the radiant in *Gemini* (36), belonged to the latter class, while others (of the same system ?) were noted very slow and red. This anomaly may perhaps be explained by the assumption of a double contemporary shower in *Gemini*, as in the case of the Perseids and Cassiopeids (August), and the Leonids and Leonids minor (November).

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List of 51 *Radiant-Points of Shooting Stars observed during April–December* 1876.

No. Jan. 1877.	Date of Observation.	Radiant-Point. R.A. °	Dec. N. °	Name or Position of Shower.	No. of Meteors.	Notes.
1	March 16—April 22	142	49	θ Ursids	6	Meteors small; rapid; a feeble radiant.
2	April 11—May 21	241	24	Coronids	8	Small; white; rapid; no streaks; accurate.
3	April 11–22	230	38	μ Boötis	8	Small; not rapid; accurate.
4	April 13—May 19	207	48	η Ursids	13	Small; short; rapid; an active shower.
5	April 13–22	194	30	Coma Berenicis	7	Small; max. April 15.
6	April 13–22	195	2 S.	Virgo	10	Rather bright; slow; an active shower.
	April 17—May 2	207	7 S.	κ Virginis	5	Small; probably same as last with mean = 201° 4° S. 15 meteors.
7	April 14—May	277	57	Draconids	6	Small; short, and very rapid; white.
8	May	221	6 S.	Libra	6	Approximate; a feeble shower.
9	July 16—Aug. 25	330	70	Cepheids	18	Small; white; very rapid; like *Draconids* (12); max. July 19–20; an active shower.
10	July 16—Aug. 14	18	63	Cassiopeids I.	28	Very bright; rapid; with streaks like *Perseids* (16); max. July 24; an active shower.
11	July 16—Aug. 25	349	24	Pegasids	8	Very slow; feeble.
12	July 16—Aug. 16	284	57	Draconids	21	Small; white; very rapid; max. July 16–18; an active shower.
13	July 16–25	337	7 S.	Aquarids	4	Bright streaks; rather slow; continued in September.
14	July 16—Sept. 17	298	2	Aquilids	14	Bright; very slow; ruddy; continued in September; a fine shower.

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15	July 16—Aug. 16	340	42	Lacertids	7	Small; white; rapid; no streaks or trains. Mean of the 3 showers = 344° + 42°; 17 meteors July 16—Nov. 20.
	Sept. 16—Oct. 25	346	44	„	6	
	Nov. 8–20	344	42	„	4	
16	Aug. 5–12	43	59	Perseids	43	Very bright; rapid; bright streaks; max. Aug. 10; very fine shower.
17	July—Aug.	6	27	α Andromedæ	7	Rapid; fairly accurate; feeble.
18	July—Aug.—Sept. 20	313	41	Cygnids	8	Rapid; white.
19	Sept. 17—Nov. 8	15	11	Piscids	17	Bright; very slow; ruddy; trains; mean of 2 showers; continued in December; active shower.
20	Sept. 18—Oct. 21	14	50	Cassiopeïds II.	13	Small; rather slow; active shower; mean = 15° + 52°; 20 meteors.
	Nov. 7–8	17	53	„	7	
21	Sept. 17—Oct. 25	317	57	Cepheids	10	Small; very rapid; white; mean of 2 feeble showers.
22	Sept. 20—Oct. 29	161	84	Polarids	7	Very, very rapid; white; position approximate.
23	Sept. 20—Oct. 25	31	37	Triangulum	9	Probably same shower, with mean at 35° + 39°; feeble.
		40	40	β Persei		
24	Sept. 20—Oct. 25	46	26	Muscids	19	Small; rapid; white; max. Oct. 15; an active shower in October.
25	Oct. 13—Nov. 20	85	33	θ Aurigids	7	Small; rather slow; ruddy; possibly same as 37.
26	Oct. 13–25	48	71	Camelopardus	7	Small; somewhat slow like *Cassiopeïds* II.; mean of 2 feeble showers.
27	Oct. 13—Nov. 20	125	47	Lynxids	17	Rapid; white; streaks; max. Oct. 29.
28	Oct. 14–17	38	12	μ Ceti	5	Very slow; a feeble shower; probably same as *Piscids* (19).
29	Oct. 14–25	90	58	δ Aurigæ	6	Bright; rapid; a feeble shower; rather uncertain.

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No. Jan. 1877.	Date of Observation.	Radiant-Point. R.A. °	Dec. N. °	Name or Position of Shower.	No. of Meteors.	Notes.
30	Oct.	358	26	α Andromedæ	7	Bright; slow; approximate.
31	Oct. 17–25	88	17	Orionids	8	Bright, with streaks; max. Oct. 17–19.
32	Oct. 21–29	61	18	Taurids I.	6	Bright; not rapid; sometimes with streaks; max. Nov. 8; a fine active shower; mean of the 3 positions = 60° + 19°; 25 meteors.
	Nov. 8	58	16	„	8	
	Nov. 19–20	62	22	„	11	
33	Oct. 25—Nov. 20	110	23	Gemillids	11	Small; very, very rapid; max. Oct. 30; quite distinct to No. 36.
34	Nov. 8–20	69	66	H. 17 Camelopardi	8	Small; rather slow; continuation of No. 26; max. about Nov. 19-20, or Dec. 6; an active shower.
	Dec. 4–8	70	67	„	6	
35	Nov. 20–28	78	43	Aurigids	9	Small; rapid; white; max. Dec. 13; mean of the 2 showers 79° + 46°; 21 meteors.
	Dec. 8–14	79	49	„	12	
36	Nov. 21—Dec. 8	103	31	Geminids	20	Very bright; slow; often ruddy, with streaks; max. Dec. 12; mean of the 2 showers, 106° + 32°; 44 meteors; a very fine shower.
	Dec. 11–21	109	33	„	24	
37	Nov. 22—Dec. 8	80	23	Taurids II.	20	Bright; very slow; max. Dec. 6; fine shower; new.
38	Nov. 19–20	149	22	Leonids	5	Rapid; white; bright streaks; a feeble and late return of the great shower; max. 1866.
39	Nov. 8—Dec. 13	140	65	ο Ursids	16	Rapid; white; mean of 2 showers.
40	Nov. 7–25	299	50	Cygnids	5	A feeble shower.
41	Nov. 20—Dec. 13	155	36	Leonids Minor	26	Bright; rapid; white; with streaks like *Leonids* (38); a very fine a.m. shower.

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42	Nov. 20—Dec. 13	342	65	Cepheus	14	Somewhat slow; new (?); rather uncertain, and perhaps confused with *Cassiopeïds* (20); and *Cygnids* (40).
43	Nov. 21—Dec. 20	208	43	η Ursids	17	Small; short; rather swift; max. Nov. 26; an active shower; new.
44	Nov. 20—Dec. 12	208	71	β Ursæ Minoris	11	A feeble shower; new; a.m.
45	Nov. 25–28	212	18	α Boötis	7	Small; feeble; max. Nov. 28; a new a.m. shower.
46	Nov. 25—Dec. 21	148	2	Sextantids	11	Bright; very rapid; white; with streaks like *Craterids* (47); somewhat feeble; a.m. new.
47	Nov. 25—Dec. 21	165	6 S.	Craterids	11	Bright; very rapid; white, with bright streaks; a fine shower; max. Dec. 21 (?); new; distinct from preceding; a.m.
48	Nov. 25—Dec.	187	37	Canes Venatici	6	Small; rather slow; uncertain, and perhaps confused with Nos. 43 and 50.
49	Nov. 25—Dec. 13	112	13	β Canis Minoris	7	A feeble shower.
50	Nov. 27—Dec. 12	179	29	Coma Berenicis	8	Small; short; not rapid, like No. 43; max. Nov. 27; new; a feeble a.m. shower.
51	Dec. 12–21	221	53	Quadrantids (?)	8	Rather slow; white; streaks.

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List of the Observed Paths of 85 Bright Shooting Stars recorded during the Nine Months, April to December 1876.

No.	Date. 1876.	Mean Time. h	m	Magnitude.	Path From R.A. °	D.N. °	To R.A. °	Dec. N. °	Length of Path.	No. of Radiant in List.	Notes.
1	April 13	10	3	1	206	50	213	73	23	6	Slow; no streak.
2	„	10	52	1	251	66	248	50	15	Polaris?	Slow; no streak.
3	14	8	26	1	197	37	226	26	34	Ursa	Very slow, 2½ secs.; rapid at first, then slow, coming almost stationary at the end.
4	„	9	48	α Lyræ	150	12 S.	131	4 S.	21	?	Rather doubtful path.
5	15	8	31	> ♀	90	24	52	31	34	6?	Pear-shaped fireball; rather swift; white; no streak; rather uncertain direction.
6	20	10	45	1	235	10	250	17	15	6	Very slow; in clouds.
7	22	9	58	1	290	43	316	47	19	α Lyræ	Slow; white.
8	„	10	28	1	245	13	256	18	11	6	
9	25	9	51	1	13	83	32	68	16	?	Not rapid.
10	May 8	9	17	> 1	281	40	312	51	24	6 or 8	Slow; no streak.
11	10	10	58	1	278	41	296	56	18	α Ophiuchi	Rather doubtful path.
12	11	9	56	1	236	53	216	64	16	„	
13	July 15	11	5	1	251	49	237	44	11	12	Very rapid; white; no streak.
14	16	10	30	1	240	18	221	20	18	14	Slow; streak.
15	„	11	17	1	260	80	225	67	15	10	Rapid; streak, 2 secs.
16	18	11	20	> 1	211	49	206	18	31	10	Rapid; bright streak.
17	19	10	58	¼	346	25	337	12	20	10	Not very rapid; streak 1½ sec.
18	20	11	29	1	341	6	335	8 S.	15	10?	Streak 1½ sec.
19	„	11	42	1	338	32	342	21	11	9	Rapid; no streak.

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20		„	11	50	> ♃	337	7 S.	346	18	26	Aquarius	Rapid; sparks and streak.
21		21	10	26	♀	306	27	317	49	24	14	Rather slow; streak 2 secs.
22		24	10	39	I	268	79	231	67	15	10	Bright streak.
23		„	10	44	> I	253	79	225	67	14	10	Bright streak.
24		„	11	28	I	344	11	356	39	30	13	Rather slow; streak.
25		„	11	34	♃	38	53	55	39	19	12	No streak.
26		25	10	55	I	276	4	275	5 S.	9	α Lyræ	Rapid; white; no streak.
27		„	11	19	I	326	23	345	31	18	14	Very slow; streak.
28		31	9	43	Sirius	284	10	286	10 S.	20	α Lyræ	Rather swift; no streak; clouds.
29	Aug.	5	10	12	I	62	71	95	69	11	10	
30		„	10	12	♃	20	47	8	38	23	16	Bright streak.
31		„	10	40	♃	199	54	207	19	35	16	Not very swift.
32		8	10	33	I	44	46	44½	37	9	10	Streak.
33		„	11	20	I	26	23	25	11	12	16	Rapid.
34		„	11	57	♃	6	25	356	39	16	Pegasid	Not very rapid; bright streak.
35		10	9	28	> ♃	53	79	214	74	27	16	Rapid; streak 2 secs.
36		„	9	54	2 × ♀	85	78	183	68	27	16	Rapid; streak for 5½ minutes, at about 151° + 78°.
37		„	11	59	I	50	20	51	14	6	16	Rapid.
38		„	12	59	♃	27	20	23	11	10	16	Rapid.
39		„	13	49	I	101	76	161	71	17	16	Rather uncertain.
40		„	14	28	I	219	84	220	71	13	16	Rapid.
41		„	15	13	I	15	22	9	7	16	16	Rapid.
42		11	10	27	I	315	9	307	3	15	...	Rapid; streak.
43		„	10	38	♃	151	69	170	53	19	16	Rapid; streak.

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No.	Date. 1876.	Mean Time. h	m	Magnitude.	Path From R.A. °	From D.N. °	To RA. °	To Dec. N. °	Length of Path.	No. of Radiant in List.	Notes.
44	Aug. 11	11	20	> ♀	196	68	210	47	22	16	Rapid; streak 1 minute.
45	„	13	50	1	108	62	128	55	12	16	Rapid; no streak.
46	14	11	35	1	212	42	204	36	9	12	Shone out like a star almost stationary at the end.
47	15	9	26	♀	208	25	186	23	20	14	Very slow; pear shaped.
48	21	9	20	1	179	51	171	46	7	12	Rapid; rather doubtful.
49	24	9	20	1	37	64	36	74	10	24	Streak.
50	Sept. 10	8	15	1	40	54	6	60	19	α Aurigæ	Rather slow; bright streak.
51	19	10	14	4	11	1	8½	2½ S.	5	19	Very short and slow; 2½ secs. near its rad. bright streak 3 minutes.
52	20	9	47	1	22	42	356	43	19	23	Rapid; streak.
53	Oct. 13	10	13	1	64	53	83	55	12	23	Rapid; no streak.
54	14	11	19	4	43	22	30	2 S.	27	29	Rapid; long streak.
55	15	6	17	1	7	24	18	22	10	30	Very, very slow; twilight.
56	21	7	6	1	336	1	329	9 S.	12	30 (?)	Rapid; no streak.
57	„	11	6	1	21	11	25	2	10	30	Slow.
58	Nov. 1	8	35	4	347	18	348	9 S.	28	42	Slow; full moon; rather doubtful.
59	7	8	15	1	88	67	104	65	7	34	Rather slow; streak.
60	8	5	6	> ♀ (?)	236	50	241	35	16	32	Very slow; streak; seen in daylight; uncertain.
61	„	6	35	> 1	339	29	289	9	50	32	Rather slow; 3 secs.; streak.
62	„	6	57	1·5	329	30	284	10	46	32	Not swift.

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63	„	8	59	1	8	19	346	17	20	32		Streak; 5 secs.
64	9	8	58	1	44	6	32	4 S.	16	32		Doubtful path.
65	20	7	27	1	79	50	103	64	19	32		Not rapid; streak.
66	„	8	37	1	20	10	25	14 S.	25	42		White; rapid; uncertain.
67	25	17	31	>1	248	52	268	44	16	41		Rapid; white; bright streak.
68	26	16	32	1	145	67	220	59	32	37		Slow; red; 2 maxima.
69	27	16	9	1	159	10 S.	184	18	25	49		Rapid; white.
70	28	17	18	1	179	74	235	67	14	39		Very rapid; white.
71	„	18	5	1	175	34	184	33	8	41		Very rapid.
72	Dec. 6	7	8	1	90	35	96	38	5	37		Very slow; near rad.
73	„	9	35	1	103	5	104	3 S.	8	36		Red; streak.
74	8	10	16	4	118	44	128	48	8	36		Slow; streak 2½ secs.
75	11	11	17	>1	55	4	45	3 S.	12	36	(?)	Rapid; white.
76	12	6	54	1	119	78	266	76	24	36		Not rapid; streak.
77	„	8	15	less than ♀	106	37	102	43	7	36		Very, very slow; ruddy; streak 10 secs.
78	„	8	47	1	156	52	133	42	18	51		Rapid; white.
79	„	16	2	1	183	41	200	37	14	36	(?)	Rapid; white.
80	„	18	18	4	202	19	218	12	10	36 or 41		Rapid; streak 6°, 7 sec.
81	„	18	34	1	199	13 S.	218	24 S.	21	36		Slow.
82	13	10	58	1	144	12	162	17	17	Monoceros		Slow.
83	19	10	20	>♀	43	13	24	4	21	36		Slow, 1·5 sec.; cloudy.
84	21	10	31	4	144	33	162	31	16	36		Slow.
85	„	14	53	1	142	28	122	7	27	51		Very rapid, white.

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Observations of Occultations of Stars by the Moon, and of Phenomena of Jupiter's Satellites, made at the Royal Observatory, Greenwich, in the year 1876.

(*Communicated by the Astronomer Royal.*)

Occultation of Stars by the Moon.

Day of Obs. 1876.	Phenomenon.		Telescope.*	Power.	Moon's Limb.	Mean Solar Time of Observation. h m s	Observer.
Feb. 2	Disapp.	of 27 Arietis	E. Eq.	140	Dark	6 30 19·3	L
April 7	„	Piazzi XII. 111	„	„	„	8 27 53·9	C
„	„	*f* Virginis	Altaz.	100	„	11 38 21·7	C
11	Reapp.	*b* Scorpii	„	„	„	11 56 51·2	C
May 5	Disapp.	50 Virginis	E. Eq.	140	„	12 0 43·0	A D
Aug. 13	„	χ' Tauri	Altaz.	100	Bright	12 19 20·5	G
Nov. 29	„	47 Arietis	E. Eq.	140	Dark	7 57 28·4	T
„	„	47 Arietis	S.E. Eq.	220	„	7 57 28·2	M

Phenomena of Jupiter's Satellites.

Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer.
Apr. 8	I (*a*)	Occ. reapp. first cont.	S.E. Eq.	130	13 18 28		
„	I	„ bisection	„	„	13 20 52	13 18	M
„	I	„ last cont.	„	„	13 26 59		
15	I	Ecl. disapp.	E. Eq.	140	12 11 56·3	12 12 1·5	R P
20	II (*b*)	Tr. eg. first cont.	„	„	11 28 58		
„	II	„ last cont.	„	„	11 31 12	11 26	T
May 1	I (*c*)	Ecl. disapp.	„	„	10 28 11·4	10 28 2·3	A D
„	I (*d*)	Occ. reap. first cont.	„	„	12 59 37		
„	I	„ last cont.	„	„	13 1 41	13 0	A D
4	II	Tr. ing. bisection	„	„	13 29 36		
„	II	„ last cont.	„	„	13 31 51	13 28	P
6	II (*e*)	Occ. reapp. first cont.	„	310	10 0 19	10 3	C
9	I (*f*)	Tr. eg. last cont.	„	140	11 53 10	11 51	A D
20	II	Occ. disapp. first cont.	„	310	11 59 21		
„	II	„ bisection	„	„	12 1 50	12 1	A D
„	II	„ last cont.	„	„	12 3 20		

* The clear aperture of the object-glass of the S.E. Equatoreal is 12¾ inches, of the East Equatoreal 6·7 inches, of the North Equatoreal 4·1 inches, and of the Altazimuth 3¾ inches.

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Day of Obs. 1875.	Satellite.	Phenomenon.	Telescope.	Power.	Mean Solar Time of Observation. h m s	Mean Solar Time from N.A. h m s	Observer.
May 29	II	Tr. eg. first cont.	„	„	11 45 53		
„	II	„ bisection	„	„	11 47 22	11 49	C
„	II	„ last cont.	„	„	11 49 7		
June 24	I (*g*)	Tr. eg. last cont.	„	140	11 29 46	11 14	L
July 3	III	„ last cont.	„	„	11 9 12	11 10	T

Notes.

(*a*) The limb of *Jupiter* was very tremulous.

(*b*), (*d*), (*e*) The limbs of the planet were badly defined.

(*c*) The first diminution of brightness was observed $2^m 15^s$ before the time here recorded.

(*f*) The observation was not satisfactory.

(*g*) The image of *Jupiter* was very bad. The recorded time is evidently erroneous.

The initials L, C, AD, M, T, G, P, and RP, are those of Mr. Lynn, Mr. Criswick, Mr. Downing, Mr. Maunder, Mr. Thackeray, Mr. Graham, Mr. Pulley, and Mr. Pett respectively.

Royal Observatory, Greenwich,
1877, *January* 13.

Stars to be compared in R. A. with Mars 1877, *for Determination of the Parallax of Mars.*

(*Communicated by the Astronomer Royal.*)

The stars in the accompanying list have been selected from those given on the chart in the *Monthly Notices* for 1875, November, as being suitable for equatoreal observations of the differences of their R. A. and that of *Mars*, east and west of the meridian. They have been arranged in pairs, one star preceding and the other following *Mars*; and as a fresh setting of the Equatoreal in N.P.D. will usually be required for each object, an interval of at least three minutes of time is allowed between the transit of *Mars* and that of either star. In some cases, however, a pair of stars can be found passing through the same field as *Mars*, and here a much smaller interval will be sufficient, with the advantage that a larger number of comparisons can be made, the sets being repeated in more rapid succession. Such pairs of stars are denoted by an asterisk. In order to eliminate as far as possible the effect of error of adjustment of the Equatoreal, stars have been selected at about equal distances north and south of *Mars*, and in some few instances where this was not practicable,

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two stars on one side have been given with a view to securing a due balance, it being intended that these two stars should be observed alternately in combination with *Mars* and the other star. Preference has been given to the brighter stars, but there is such a paucity of stars in this region that it has sometimes been necessary to go as low as the ninth magnitude.

The plan of observation requires a firmly-mounted Equatoreal, which can be securely clamped in Right Ascension, and provided with a transit eyepiece having a system of parallel meridional wires at convenient intervals. A number of sets of transits of *Mars* and a pair of stars should be taken in as rapid succession as possible in the evening, when *Mars* is east of the meridian and as far from it as practicable; and a corresponding number of *Mars* and the same pair of stars in the early morning, when *Mars* is far to the west, the Equatoreal being firmly clamped for each set. Both limbs of *Mars* are in all cases to be observed, over alternate wires, or otherwise, as may be found convenient, care being taken that the limb (whether first or second) observed over any particular wires in one set be observed over the other wires in the next set. The same pair of stars must be observed in the morning and evening (as has been mentioned), and when a change occurs from one day to the next, both the old and the new pair should be observed alternately on one morning or evening at least. If different observers take part in the work, care should be taken that each observer is charged as often with morning as with evening observations.

The value of the observations made at any particular station will depend largely on the interval between the evening and morning sets of comparisons; and the choice of stations is determined mainly by consideration of the available time-interval during which *Mars* is far enough above the horizon and the Sun far enough below to allow of satisfactory observations being made. Taking these "horizon allowances" as $1^h\ 20^m$ for lat. 50° N., $1^h\ 0^m$ for lat. 15° N., and $1^h\ 10^m$ for lat. 35° S., the "available time-interval" has been computed for these three latitudes; and the following table has been formed, showing, at intervals of seven days, the square of the quantity $\frac{1}{\text{dist. of } Mars}$ × cos. of station's latitude × available time-interval, which may be considered as a roughly approximate value of the square of the parallax factor, and which gives the combining weight of these observations in the determination of the Sun's Equatoreal Horizontal Parallax.

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(*Parallax Factor*)^2

			Latitude 50° N.	15° N.	35° S.
1877	July	22	23	155	180
		29	34	202	216
	August	5	50	259	269
		12	72	329	325
		19	97	405	383
		26	126	487	444
	Sept.	2	156	563	492
		9	152	586	480
		16	141	496	413
		23	125	410	330
		30	104	330	256
	Oct.	7	86	263	194
		14	71	208	144
		21	57	163	106
		28	50	129	78

Pairs of Stars to be compared in R.A. with Mars.

(The Nos. are those of Weisse's Bessel, *Cat. Stell. in Zonis Regiomontanis.* The mean places of the Stars for 1877 are given in the *Monthly Notices*, for 1875, November.)

1877.		
July 25	322, 565	427*, 508*
26	,,	,,
27	427, 586	
28	,,	
29	,,	
30	427, 619, 629	
31	,,	
Aug. 1	,,	
2	,,	
3	,,	
4	,,	
5	,,	
6	,,	
7	,,	
8	,,	
9	,,	
10	,,	

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1877.		
Aug. 11	427, 619	
12	,,	
13	,,	
14	,,	
15	427, 583	
16	,,	
17	,,	
18	377, 583	
19	,,	
20	,,	
21	377, 497	
22	,,	
23	315, 497	
24	315, P. XXIII. 109	
25	,,	
26	265, 497	
27	265, 402	309*, * (R.A. 19h 55m N.P.D. 101°22′)*
28	,,	286*, 385*
29	ψ² Aquarii, 402, 403	
30	,,	
31	ψ² Aquarii, 373	185*, 309*
Sept. 1	Lal. 45504, 309	,,
2	,,	,,
3	57, 265	Lal. 45504*, 309*
4	,,	,,
5	,,	,,
6	49, 228, 270	57*, Lal. 45504*
7	1276, 185	,,
8	,,	,,
9	1261, Lal. 45504	1261*, 57*
10	,,	,,
11	1204, 57	,,
12	,,	,,
13	,,	,,
14	1129, 12, 14	1204*, 1261*
15	,,	,,
16	,,	
17	1079, 1261	1129*, 1204
18	,,	

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1877.				
Sept. 19		966, 1204		
20			966*, 1129*	
21			,,	
22		74 Aquarii, 1165	,,	
23		,,	,,	
24		,,	,,	
25		,,	,,	
26		,,	,,	
27	918, 1129	935, 1156	70 Aquarii, 1079	966*, 1129*
28		70 Aquarii, 1079		
29		,,		
30		,,		
Oct. 1		,,		
2		,,		
3		,,	74 Aquarii (conjunction)	
4		,,	,,	
5		,,	,,	
6		,,		
7		,,		
8		,,		
9		,,		
10		70 Aquarii, 1047, 1079		
11		,,	926*, 1007*	
12		,,	,,	
13		,,		
14		70 Aquarii, 1065		
15		910, 1047	70 Aquarii, 1122	
16		70 Aquarii, 1122	946*, 70 Aquarii*, 1020*	
17		70 Aquarii, 1120	977*, 946*, 1020*, 1017*	
18		,,	994*, 933*, 1017*	

Royal Observatory, Greenwich,
1877, *January* 13.

On O. M. Mitchel's Observations at Cincinnati.

By Cleveland Abbe, Esq.

In a note to his recently-published "Reference Catalogue" Mr. Knobel calls attention to the fact that copies of Mitchel's *Sidereal Messenger* are very rare in England, and to the Supplementary note in *Nature* (November 9, page 49). I would add,

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that complete sets of this interesting periodical are almost equally as rare in America.* Rarer still is to be found nowadays the excellent text-book for schools and hand-book for amateurs, published in 1849, in Cincinnati, New York, as "Mitchel's edition of Burritt's *Geography of the Heavens*." In this book Mitchel published numerous notes based on the work done during 1845–48 at his Observatory, and I have thought it may interest members of the Astronomical Society if I copy from it for their use the record of double star positions observed at Cincinnati. These few figures, however, convey but a faint idea of Mitchel's activity during those years: in my annual reports, 1868, 1869, and 1870, I have given a nearly full list of his publications, and expressed the hope that I should be able to prepare for publication such of his observations (especially the very extensive series of zones of faint stars) as gave promise of being useful; and although this is now become a very difficult matter, owing to the death of Mitchel and his faithful assistant Twitchel, yet possibly my successor may be induced to undertake it.

In the accompanying table reference is given in the last column to the page of Mitchel's edition of Burritt. I have also included the name of Nebulæ, etc., concerning which Mitchel gives some notes as to their appearance at Cincinnati; these notes are generally somewhat general and unsatisfactory in their nature, but I shall be happy to communicate them in full if desired. I fear lest an occasional typographical mistake may have crept into the measurements here given; but possibly these may at some future time be rectified if ever the original observer's note-book can be found.†

Washington,
1876, *December* 15.

Observations of Double Stars, by O. M. Mitchel, made between May 1845 *and May* 1848, *with the* 12*-inch Refractor, at Cincinnati.*

(*From Mitchel's "Geography of the Heavens," New York*, 1849.)

No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
1	38 Piscium	0 9	+ 7 59	235 59	4·646	1847·65	54
2	55 ,,	0 31	+20 33	191 52	7·014	1847·65	54
3	τ Cassiopeiæ	0 39	+50 34	146 25	2·24	1847·60	49
4	η ,,	0 39	+56 57	101 20	8·59	1847·60	49
5	65 Piscium	0 41	+26 50	297 32	...	1847·65	54

* The Astor Library, in New York City, possesses a few of the last published numbers, which are, I believe, wanting in all the other sets that I have hitherto seen.

† The names of Nebulæ are omitted from the Table as printed, and the Double Stars have been rearranged in order of Right Ascension.—Ed.

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No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
6	36 Andromedæ	0 46	+22	330 14	1·050	1847·70	39
7	ψ Cassiopeiæ (A & B)	1 14	+67 14	102 37	30·394	1847·60	49
8	„ „ (B & C)	„ „	„ „	253 7	32·856	1847·60	50
9	γ Arietis	1 44	+18 30	175 37	9·184	1847·65	60
10	α Piscium	1 53	+ 1 59	330 3	...	1847·65	55
11	γ Andromedæ	1 54	+41	110 0	0·40	1846·60	40
12	γ Virginis	12 33	− 0 34	357 28	3·09	1847·60	116
13	Comæ Ber. (A & B)	12 45	+22 7	40 4	1·316	1847·57	135
14	„ (A & C)	„ „	„ „	125 31	...	1847·57	135
15	84 Virginis	13 35	+ 4 21	231 5	3·48	1847·06	118
16	π Boötis	14 33	+17 6	96 57	8·28	1847·60	128
17	ζ „	14 33	+14 25	128 24	6·924	1847·62	128
18	ε „	14 38	+27 45	320 50	2·568	1846·66	128
19	ξ „	14 44	+19 46	317 44	6·482	1847·63	129
20	39 „	14 44	+49 22	37 0	4·00	1847·60	129
21	44 „	14 58	+48 16	238 20	3·738	1847·62	129
22	β Scorpii	15 56	−19 21	26 22	13·68	1846·50	147
23	51 ξ Libræ (A & B)	15 58	−10 55	24 52	0·97	1846·48	143
24	„ „ (A & C)	„ „	„ „	74 42	7·16	1846·48	143
25	ν Scorpii (A & B)	16 2	−19 2	37 57	1·2	1846·(?)	146
26	„ „ (½ A B & C)	„ „	„ „	338 29	40·0	1846·(?)	146
27	σ Scorpii	16 11	−25 12	271 5	22·34	1847·60	147
28	α „	16 19	−26 4	90 0	2·5	1845·5(?)	146
29	XIV Piazzi 88	16 20	− 7 45	304 14	5·292	1847·70	186
30	λ Ophiuchi	16 22	+ 2 20	3 42	1·42	1847·65	183
31	ζ Herculis	16 35	+31 53	109 12	1·078	1847·70	163
32	η „	16 37	+39 13	...	inseparable	...	163
33		16 54	+ 8 41	146 57	0·826	1847·70	185
34	μ Draconis	17 2	+54 41	190 57	2·90	1847·70	133
35	36	17 5	−26 21	215 49	4·27	1847·62	185
36	α Herculis	17 7	+14 34	117 36	4·92	1847·62	162
37		17 17	+15 45	62 33	3·654	1847·60	185
38	Draconis	17 25	+50 59	266 20	3·03	1847·70	133
39	τ Ophiuchi	17 54	− 8 10	229 24	0·779	1846·51	183
40	p=70 Ophiuchi	17 57	+ 2 32	120 45	5·53	1847·55	183
41	73	18 1	+ 3 58	253 0	1·274	1847·55	185
42	ε Lyræ (A & B)	18 39	39 30	20 25	2·46	1847·60	172
43	5 „ (C & D)	„ „	„ „	149 10	2·55	1847·60	172

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No.	Constellation and Object.	R.A. h m	Dec. ° ′	Position-Angle. ° ′	Distance. ″	Epoch.	Page.
44	Aquilæ (B & C)	18 54	− 0 55	76 0	1·576	1847·60	176
45	Aquilæ	18 57	+ 6 18	152 28	9·492	1847·65	176
46	23 Aquilæ	19 10	+ 0 48	12 9	3·57	1847 67	177
47	Aquilæ (A & B)	19 28	−10 46	319 4	2·54	1847·60	176
48	„ (A & C)	„ „	„ „	169 17	...	...	176
49	Aquilæ	19 37	+10 23	276 36	4·33	1847·72	177
50	π Aquilæ	19 41	+11 25	123 9	1·20	1847·66	176
51	α^2 Capricorni	20 9	−13 2	144 11	6·36	1846·67	195
52	ρ „	20 19	−18 20	176 56	3·094	1847·70	195
53	XX Piazzi, 376 Equulei	20 47	+ 3 55	287 45	1·874	1847·65	189
54	ε Equulei (A & B)	20 51	+ 3 41	288 6	0·574	1847·60	189
55	„ „ (A & C)	„ „	„ „	76 25	11·08	1847·60	189
56	λ „	20 54	+ 6 33	227 42	1·9	1847·60	189
57	12 Aquarii	20 55	− 6 27	191 30	8·23	1847·63	192
58	61 Cygni	20 59	+37 58	101 2	17·3	1847·50	167
59	29 Aquarii	21 53	−17 43	242 8	4·466	1847·70	192
60	41 „	22 5	−21 51	120 22	4·326	1847·70	193
61	Pegasi	22 6	+16 24	331 29	8·03	1847·65	188
62	ζ Aquarii	22 20	− 0 50	346 42	3·948	1847·70	193
63	37 Pegasi	22 21	+ 3 37	121 46	0·98	1847·70	188
64	Aquarii	22 34	− 9 8	314 35	1·82	1847·70	193
65	Piscium	23 37	− 0 37	227 33	2·702	1847·65	35

On the Space-penetrating Power of Mr. Lassell's 2-foot and 4-foot Reflectors. By W. Lassell, Esq.

In the *Monthly Notices* for December is a note by M. Otto Struve, in which, quoting from a previously written paper, he says, "The space-penetrating power of Mr. Lassell's new (4-feet) instrument can hardly be estimated superior to that of ours (the Pulkova 15-inch) Refractor." There appears to me to be something so erroneous in this conclusion, that although very averse to controversy, and especially to enter the lists with my very distinguished friend, M. Struve, I crave permission to state my greatly differing opinion, and the grounds on which I have formed it.

To begin with a comparison of the powers of my 2-foot Equatoreal with those of the Pulkova telescope. About the year 1847 and later, I was engaged, as opportunities offered, in a diligent scrutiny with the view of verifying the fainter Satellites

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of *Uranus*, presumed to have been discovered by the late Sir William Herschel. It would appear from Professor Struve's communication to the *Monthly Notices*, vol. viii., pages 44 and 139, that he was then engaged in the same careful search; and he announces, with some confidence, his verification or re-discovery of at least one of Herschel's satellites, namely, that whose period was announced by Herschel to be $5^d\ 21^h\ 25^m$, adding that he had no doubt of the identity of the two objects, and that his observations "completely prove the existence of Herschel's first supplementary satellite." Yet the detailed observations at page 46 do not seem to me sufficiently exact or consistent to justify this conviction; and certainly the long series of supplementary observations of the Satellites of *Uranus* has made the conclusion irresistible that this rediscovery must be given up, and that the Pulkova telescope was not equal to the task then set before it.

The interior faint satellites, now recognised as *Umbriel* and *Ariel*, were first certainly seen by me in 1847, but I was not able to give what I thought a sufficiently distinct account of them until 1851; and I would especially direct attention to my letters of the 13th and 29th November in the latter year (*Monthly Notices*, vol. xii., page 15), as proving by the precision, certainty, and frequency with which the objects were seen, that the 2-foot Reflector must have been even greatly superior to the 15-inch Refractor. I may, perhaps, add also the opinion of the late Mr. G. P. Bond, expressed verbally to myself, that my 2-foot telescope was sensibly more efficient than the Harvard Telescope, which may be called a facsimile of that at Pulkova.

I will now refer to vol. xxxvi. of the *Memoirs*, containing the record of my observations at Malta with the 4-foot Equatoreal, as proving the superiority of that telescope in illuminating or "space-penetrating" power, to the 2-foot Equatoreal.

At page 34 an observation of *Uranus* and his Satellites is recorded, together with an expression of my opinion of the comparative efficiency of these telescopes on these objects, and asserting the great superiority of the 4-foot. Again, at page 36, on September 27th there is recorded an observation of δ *Cygni*, in which the 2-foot is again mentioned, with a remark in favour of the 4-foot. Further, at pages 7 and 8, observations of the Satellite of Neptune made on August 2nd, September 22nd, and October 19th, are given, when the satellite was observed nearer to the limb of the planet than it had ever been seen in the 2-foot. Moreover, I may remark that the observation of a faint satellite very near to its primary in two telescopes differing greatly in size, tells disproportionately against the larger one; since the greater brightness of the planet diminishes the sensibility of the eye for detection of the satellites—in addition also to the greater disturbance of the atmosphere with the larger aperture.

Lastly, in further corroboration of the superiority of the 4-foot, I may suggest a comparison of the figured Nebulæ in this volume with such of them as are contained in vol. xxiii.

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of the *Memoirs*, in my paper giving observations with the 2-foot.

I conclude with remarking that Professor Struve's unfavourable impression may perhaps in some degree have arisen from his visit to Malta having been made at a time of the year when the atmosphere is occasionally much disturbed by storms, which are of course greatly to the disadvantage of a very large telescope.

Ray Lodge, Maidenhead,
1877, January 23.

The Specular Reflexion Hypothesis, and its bearing on the Transit of Venus. By John Brett.

There was a phenomenon observed at the transit of *Venus* (the ring of light at the planet's limb), which, as far as I know, has not hitherto been explained, and my present purpose is to show that the specular reflexion hypothesis has an important bearing on this subject. If, in addition to a burnished reflecting surface, we suppose *Venus* to have a translucent envelope of great density, it appears to me that all the elements necessary for a complete explanation of the mystery are at hand; at all events, it is possible on these terms to produce a very similar phenomenon experimentally.

In my last I ventured to suggest a reason for believing the surface of the planet to be in a molten or vitrified state.

That suggestion was peculiarly fortunate in having attracted the attention of Mr. Christie, whose investigations afford, at all events, invaluable data for studying the subject, if not (as I believe) a complete confirmation of the hypothesis. *Vide* last Number of the *Monthly Notices*.

The theory of specular reflexion is, of course, perfectly well understood, and its phenomena in the case of *Venus* and the Sun would occur as follow:—At superior conjunction we should see merely a small circular image of the Sun. In the course of the planet's progress in its orbit, this image would move in longitude and extend itself in latitude, assuming a cusped crescent form. Near the time of inferior conjunction it would approach the limb, and present an extremely attenuated rim of light. At transit this rim would completely encircle the disk, and theoretically would never entirely disappear. Even practically, the Sun's light near his limb is so much weaker than at the centre, that it is quite conceivable that the ring, or reflected image, might be observed during the earliest and latest stages of the transit. The position this ring would occupy within the planet's limb can of course be determined with accuracy by a calculation based on the relative diameters of the Sun and planet.

So far the theory is simple, and has been so well understood for ages that no illustration is needed.

It will, however, be perceived that any expansion in latitude of this extremely attenuated ring which might have been ob-

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served at transit (and I understand that the photographs prove such to have been the case), would introduce other and more complicated considerations into the problem, indicating, as I suppose it would, the existence of a refractive envelope or atmosphere. Now, any diffusion or extension of the area of the ring would of course weaken the intensity of its light, not to mention the question of absorption. Before contact, however, these considerations would not at all damage the theory. The great difficulty arises when we find a diffused ring of light surrounding the planet whilst actually on the Sun's disk surpassing in brilliancy his direct rays. If there are no theoretical objections to the planet's surface existing in a state of fusion, or at all events, to have so existed, it is not unreasonable to suppose that the metallic constituents of its substance would settle at a lower level than its lighter or vitreous elements: we might thus imagine a molten metallic lustrous surface overlaid and protected by an envelope of glass.

There is, I suppose, no doubt that the lenticular action of an atmosphere of great refractive power would be effective to bend over the limb, and produce in a condensed state, some of the rays which impinge on the planet immediately *beyond* the limb, and in that way it seems to me that a certain degree of increased brilliancy would be produced; but if we are allowed to assume the existence of a vitreous envelope, it is evident that, in addition to the correction of the divergence of such rays as have been reflected from a zone of the burnished surface *immediately* behind the limb, a quantity of light reflected from another zone still further beyond the limb, would be condensed by *interior* reflexion from the surface of the vitreous envelope, acting in the sense of a concave mirror, and produced over the limb towards the Earth, so as to give a luminous halo of greater brilliancy than the Sun itself. The little instrument which I invite the Fellows to look into after the meeting shows that such a result can be experimentally produced.

It consists, first, of a small globe representing *Venus* suspended within a tube; secondly, of a collimator; and, thirdly, of a microscope focussed upon the limb of the little globe. The little globe or model of *Venus* consists of a glass bulb filled with mercury.

When this instrument is directed to a gas-lamp the ring of condensed light is very plainly seen; and I think that although the apparatus is very rudely and imperfectly made, it does all that can be expected of it.

I now ask leave to add one more suggestion, as follows:—

At the next transit it would be worth while for some one with a good telescope and a Dawes-diaphragm to look at the centre of *Venus's* disk for the reflected image of the Earth. If the envelope of the planet has great refractive power, I think it not improbable that it might be seen as a minute nebulous speck of light.

38 *Harley Street, London,*
1877, *January* 12.

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An Improved Mode of viewing the Sun.

By Wentworth Erck, Esq.

A Barlow-lens is first employed to enlarge the image, and then, by means of a small, unsilvered, elliptical, plane, glass surface a minute portion of the pencil, forming the enlarged image, is deflected into the eyepiece; the remainder of the pencil, which may be $\frac{97}{100}$ths of the whole, escaping, freely, and therefore without heating, into the open air.

For example: The image formed by my object-glass is an inch in diameter; this is doubled by a Barlow of 8-inches negative focus, while the minor axis of the elliptical reflector is only $\frac{1}{3}$rd of an inch.

Thus it is evident that only $\frac{1}{36}$th of the entire image is transmitted to the eyepiece, and the remaining $\frac{35}{36}$ths escape freely into the open air.

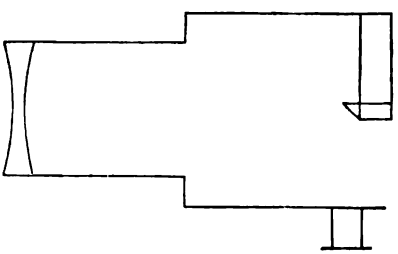
But of the $\frac{1}{36}$th that would reach the eyepiece, only $\frac{1}{10}$th is actually reflected by the unsilvered surface, so that the amount of heat reaching the eye, under these arrangements, is but $\frac{1}{360}$th of that which would reach the eye directly viewing the original image of the Sun.

As it is desirable to be able to examine the edge of the disk in the centre of the field, and also desirable that no part of the pencil should impinge upon metal work, it follows that the clear aperture of the Barlow should be at least twice the diameter of the principal image; and the tube, carrying the eyepiece, should be four times that diameter.

The most convenient form of reflector is a cylinder cut at an angle of 45°, and having its surface and base polished to prevent escape of heat except at the base. This cylinder is supported on a very light arm, exactly as in a Newtonian.

I can speak from experience of the great advantage of this arrangement, the eyepiece remaining even in summer perfectly cool, with $7\frac{1}{2}$-inches aperture, and the definition unimpaired so long as the telescope is kept accurately following the Sun to prevent his rays striking on the tube.

The subjoined sketch is $\frac{1}{4}$th true size.



Sherrington, Bray,
1877, *5th January.*

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. *February* 9, 1877. No. 4.

WILLIAM HUGGINS, Esq., F.R.S., President, in the Chair.

Geo. Francis Hardy, Esq., Rothbury House, Stroud Green, Finsbury Park, N.;

John Sidney White, Esq., 13 Bolton Gardens, South Kensington, S.W.; and

A. Mason Worthington, Esq., B.A., Sandiway House, Altrincham;

were balloted for and duly elected Fellows of the Society.

REPORT OF THE COUNCIL TO THE FIFTY-SEVENTH ANNUAL GENERAL MEETING OF THE SOCIETY.

Progress and present state of the Society:—

	Compounders.	Annual Subscribers.	Non-resident.	Mathematical Society.	Patroness, and Honorary.	Total Fellows.	Associates.	Grand Total.
December 31, 1875	204	348	5	7	2	566	42	608
Since elected ...	+9	+20	...	...	...	...	...	...
Deceased	−2	− 7	...	...	− 1	...	...	...
Removals	+1	− 1	...	...	...	...	...	...
Resigned	...	− 6	...	...	...	...	...	...
Expelled	...	− 1	...	...	...	...	...	...
December 31, 1876	212	353	5	7	1	578	42	620

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REPORT OF

The Report of the Auditors not having been received at the following copy of the Treasurer's signed Report submitted to

Mr. Whitbread's Account as Treasurer of the Royal

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1875	548	18	9			
In hand of Secretary of Library Committee:						
On account of Library Expenses	32	3	0			
„ Turnor Fund...	21	0	0			
In hand on Petty Cash Account	13	4	11			
				615	6	8
Dividend on £3,700 Consols	55	0	9			
„ £5,200 New 3 per Cents.	77	7	0			
„ £4,000 Consols	59	5	0			
„ £5,200 New 3 per Cents.	77	0	6			
				268	13	3
Received on account of subscriptions:						
Arrears of contributions	106	1	0			
237 Contributions for 1876	497	14	0			
On account of ditto	2	0	0			
28 Admission Fees	60	18	0			
20 first Contributions	32	11	0			
				699	4	0
11 Composition Fees	...		...	231	0	0
Sale of publications at Society's Rooms	52	18	8			
„ „ Williams & Norgate's ...	23	1	0			
				75	19	8
Balance of Horrox Memorial Fund	...		...	38	15	0
Bequest of the late T. C. Janson, Esq., to the Lee Fund	...		...	200	0	0
Bequest of the late R. C. Carrington, Esq., £2,000 Consols, transferred to the Society's account, at 94	...		...	1,880	0	0
Due to Assistant Secretary, on Petty Cash Account, Dec. 31, 1876...	...		...	2	18	8
				£4,011	17	3

SAM. CHAS. WHITBREAD,
Treasurer.

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THE TREASURER.

time of the revision of the Annual Report of the Council, the the Auditors is herewith appended.

Astronomical Society, from Dec. 31, 1875, to Dec. 31, 1876.

EXPENDITURE.

	£	s.	d.	£	s.	d.
Salaries:—						
Editor of *Monthly Notices*, 5 quarters ...	75	0	0			
Assistant Secretary, 5 quarters	187	10	0			
				262	10	0
Income Tax and House Duty	...		...	5	5	0
Fire Insurance	...		...	7	16	6
Printing:—						
Spottiswoode & Co.	364	8	0			
Hazell, Watson, & Viney	187	12	0			
Holdgate Brothers, Printing Plates... ...	18	5	0			
				570	5	0
Lithography, Engraving, &c.:—						
Chatham School of Photography	5	10	0			
W. H. Wesley	51	2	0			
				56	12	0
Binding and Stitching: J. Rumfitt	...		...	39	17	3
Library expenses, binding books, &c.	...		...	138	14	6
Turnor Fund: books purchased during year ...	...		...	48	16	3
Miscellaneous:—						
House expenses	28	7	7			
Wages...	23	17	0			
Stamps and postage	49	10	8			
Carriage of books and parcels	8	8	2			
Stationery and office expenses	8	6	0			
Expenses of meetings	17	15	6			
Coals and gas...	74	19	9			
Mrs. Jackson-Gwilt's Annuity	8	19	0			
Fittings in Library &c.: Whitechurch Bros.	5	14	6			
Sundries	20	19	8			
Bankers' commission &c.	0	0	6			
New cheque-book	0	8	4			
				247	6	8
Investments:—						
Purchase of £300 Consols, at 96⅝, including commission...	289	10	0			
Purchase of £200 Consols, at 95⅝, including commission...	191	10	0			
				481	0	0
Carrington Legacy of £2,000 Consols, transferred to Society's account, at 94	...		...	1,880	0	0
Balance at Bankers', Dec. 31, 1876	238	1	10			
In hand of Secretary of Library Committee on account of Library Expenses	13	8	6			
On account of Turnor Fund	22	3	9			
				273	14	1
				£4,011	17	3

SAM. CHAS. WHITBREAD,
Treasurer.

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Assets and present property of the Society, January 1, 1877:—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1876				238	1	10
Due on account of Subscriptions:—						
2 contributions of 5 years' standing	21	0	0			
2 „ 4 „	16	16	0			
11 „ 3 „	69	6	0			
22 „ 2 „	92	8	0			
69 „ 1 „	144	18	0			
2 admission fees	4	4	0			
2 first contributions	2	2	0			
One amount of	5	5	0			
				355	19	0
Balances in hand:—						
In hand of Secretary of Library Committee on account of Library Expenses	13	8	6			
Do. do. on account of Turnor Fund	22	3	9			
	35	12	3			
Less amount due to Assistant Secretary on Petty Cash Account, Dec. 31, 1876	2	18	8			
				32	13	7

£5,200 New 3 per Cent. Consols, including Mrs. Jackson-Gwilt's Gift (£300).
£6,200 Consols, including the Lee Fund (£300), the Turnor Fund (£450), and the Horrox Memorial Fund (£100).
Unsold Publications of the Society.
Various Astronomical Instruments, Books, Prints, &c.
Two Gold Medals in Stock.
Balance of Turnor Fund, *included in Treasurer's Account*, £129. 5*s*. 6*d*.

Stock in hand of volumes of the *Monthly Notices*:—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I.	89	3	XIV.	113	3
II.	90	3	XV.	118	2
III.	...	...	XVI.	116	3
IV.	...	...	XVII.	142	1
V.	...	...	XVIII.	171	1
VI.	55	1	XIX.	76	...
VII.	3	...	XX.	45	...
VIII.	138	2	XXI.	28	...
IX.	19	1	XXII.	44	...
X.	182	2	XXIII.	28	...
XI.	190	2	XXIV.	30	...
XII.	16	2	XXV.	10	...
XIII.	167	3	XXVI.	18	...

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Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
XXVII.	2	...	XXXIII.	136	4
XXVIII.	82	2	XXXIV.	108	4
XXIX.	68	2	XXXV.	36	4
XXX.	78	4	XXXVI.	71	2
XXXI.	118	1	Index to *Monthly Notices*	612	1
XXXII.	150	4			

In addition to the stock in hand of the volumes of the *Monthly Notices*, there are also a considerable number of separate numbers of almost every volume. These back numbers, although no complete volume can be formed from them, except of Vol. XXXVI., are available for the completion of sets.

Besides the seventy-one bound copies of Vol. XXXVI., a large number of each part are also in stock.

Stock in hand of volumes of the *Memoirs* :—

Vol.	At Society's Rooms.	At Williams & Norgate's.	Vol.	At Society's Rooms.	At Williams & Norgate's.
I. Part 1	3	...	XV.	153	1
I. Part 2	50	...	XVI.	182	...
II. Part 1	61	...	XVII.	159	4
II. Part 2	26	...	XVIII.	161	1
III. Part 1	76	...	XIX.	168	1
III. Part 2	95	...	XX.	164	1
IV. Part 1	90	3	XXI. Part 1	314	...
IV. Part 2	100	3	XXI. Part 2	99	...
V.	115	4	XXI. 1 & 2 (together)	70	1
VI.	135	4	XXII.	166	...
VII.	159	3	XXIII.	162	1
VIII.	138	3	XXIV.	167	2
IX.	146	3	XXV.	180	2
X.	157	1	XXVI.	183	2
XI.	166	1	XXVII.	437	1
XII.	170	...	XXVIII.	400	2
XIII.	184	2	XXIX.	426	1
XIV.	381	3	XXX.	176	...

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Vol.	At Society's Rooms.	At Williams & Norgate's	Vol.	At Society's Rooms.	At Williams & Norgate's
XXXI.	159	2	XXXVII. Part 2	329	5
XXXII.	181	2	XXXVIII.	327	2
XXXIII.	183	1	XXXIX. Part 1	313	3
XXXIV.	149	36	XXXIX. Part 2	333	1
XXXV.	133	2	XL.	389	3
XXXVI. (with M.N.)	212	5	XLII.	404	4
XXXVI. (without)	18	...	Index to *Memoirs*	707	5
XXXVII. Part 1	381	8			

Since the last anniversary meeting the Assistant Secretary has examined the stock of volumes of the *Memoirs* and *Monthly Notices* with the greatest care, and he has re-arranged it in a more convenient manner for future examinations. In doing this he has found several mistakes in the lettering of the different parcels, which account for some discrepancies between the lists in this and the preceding Report.

Instruments belonging to the Society.

The following is a complete list of the instruments belonging to the Society. The Council have to regret that most of those missing at the date of the last Report are still unaccounted for. It is possible, however, that a few of them may ultimately be traced, and in consequence it would be unadvisable at present to strike them out of the list.

The resolution of the Council "that the Secretaries in every November shall go through the list of the Society's instruments, and send to each person to whom any instrument belonging to the Society has been lent, a circular desiring him to return the instrument to the Society's rooms before the following January meeting, or to make a fresh application for it," has been faithfully carried out. By thus confining the loan of the instruments to one year, subject to renewal if required for a longer period, it is expected that any unexplained loss of instruments will be prevented for the future. The Council have no desire to hasten the return of an instrument when it is still of service to the borrower, but it is very desirable that it should be returned to the Society's rooms as soon as possible when no longer required.

Some interesting notes by Mr. Lecky on several of the instruments may be found on pp. 132–134 of the last Annual Report. The complete list is as follows:—

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No. 1. The *Harrison* clock,
„ 2. The *Owen* portable circles, by Jones,
„ 3. The *Beaufoy* circle,
„ 4. The *Beaufoy* transit instrument,
„ 5. The *Herschelian* 7-foot telescope,
„ 6. The *Greig* universal instrument, by Reichenbach and Ertel. The transit telescope, by Ultzschneider and Fraunhofer, of Munich,
„ 7. The *Smeaton* equatoreal,
„ 8. The *Cavendish* apparatus,
„ 9. The 7-foot Gregorian telescope (late Mr. Shearman's),
„ 10. The Variation transit instrument (late Mr. Shearman's),
„ 11. The Universal quadrant, by Abraham Sharp,
„ 12. The *Fuller* theodolite,
„ 13. The Standard scale, by Troughton and Simms,
„ 14. The *Beaufoy* clock, No. 1,
„ 15. The *Beaufoy* clock, No. 2,
„ 16. The *Wollaston* telescope,
„ 17. The *Lee* circle,
„ 18. The *Sharpe* reflecting circle,
„ 19. The *Brisbane* circle,
„ 20. The *Baker* universal equatoreal,
„ 21. The *Reade* transit,
„ 22. The *Matthew* equatoreal, by Cooke,
„ 23. The *Matthew* transit instrument,
„ 24. The *South* transit instrument,
25. A Quadrant, by Bird (formerly belonging to Captain Cook),
„ 26. A Globe showing the Precession of the Equinoxes.

The *Sheepshanks* collection:—

„ 27. (1.) 30-inch transit instrument, by Simms, with level and two iron stands.
„ 28. (2.) 6-inch transit theodolite, with circles divided on silver; reading microscopes, both for altitude and azimuth; cross and siding levels; magnetic needle; plumbline; portable clamping foot and tripod stand.
„ 29. (3.) $4\frac{8}{10}$-inch achromatic telescope, about 5 feet 6 inches focal length; finder; rack motion; two other micrometers; one terrestrial and ten astronomical eyepieces, applied by means of two adapters, with equatoreal stand clock movement.
„ 30. (4.) $3\frac{1}{2}$-inch achromatic telescope, with equatoreal stand; double-image micrometer; one terrestrial and three astronomical eyepieces.
„ 31. (5.) $2\frac{3}{4}$-inch achromatic telescope, with stand; one terrestrial and three astronomical eyepieces.

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No. 32. (6.) $2\frac{3}{4}$-inch achromatic telescope, about 30 inches focal length; one terrestrial and four astronomical eyepieces. This instrument was lent to the late Rev. J. Cape, and is believed to be lost.

„ 33. (7.) 2-foot navy telescope.

„ 34. (8.) A transit instrument of 45 inches focal length; with iron stand, and also Ys for fixing to stone piers; two axis levels.

„ 35. (9.) Repeating theodolite, by Ertel, with folding tripod stand.

„ 36. (10.) 8-inch pillar sextant, by Troughton, divided on platinum, with counterpoise stand and artificial horizon.

„ 37. (11.) Portable zenith telescope and stand, $2\frac{3}{4}$-inch aperture and 26 inches focal length; 10-inch horizontal circle and 8-inch vertical circle, read to 10″ by two verniers to each circle.

„ 38. (12.) 18-inch Borda repeating circle, by Troughton, $2\frac{1}{8}$-inch aperture and 24 inches focal length; the circles divided on silver, the horizontal circle being read by four verniers, and the vertical circle by three verniers, each to 10″.

„ 39. (13.) 8-inch vertical repeating circle, with diagonal telescope, by Troughton and Simms; circle divided on silver, reading to 10″; a 5-inch circle at eye-end reading to single minutes; horizontal circle 9 inches diameter in brass, reading to single minutes.

„ 40. (14.) A set of surveying instruments, consisting of a 12-inch theodolite for horizontal angles only, reading to 10″; two sets of adjusting plates; tripod stand with enclosed telescope; a deal box with heavy stand for theodolite; a box containing the Y piece of level; two large and three small ground-glass bubbles divided; a box containing level collimator, object-glass $1\frac{5}{8}$-inch diameter and 16 inches focal length; micrometer eyepiece, comb, and wires.

„ 41. (15.) Level collimator with object-glass $1\frac{7}{8}$-inch diameter and 16 inches focal length; stand, rider-level, and fittings.

„ 42. (16.) 10-inch reflecting circle, by Troughton, reading by three verniers to 20″; counterpoise stand; artificial horizon with mercury; two tripod stands.

„ 43. (17.) Hassler's reflecting circle, by Troughton, with counterpoise stand.

„ 44. (18.) 6-inch reflecting and repeating circle, by Troughton and Simms, contained in three boxes, two of which form stands. The circle is divided on silver, and is read to single minutes; two inside arcs divided to single degrees, 150 degrees on each side; artificial horizon and mercury.

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No. 45. (19.) 5-inch reflecting and repeating circle, by Lenoir, of Paris.
„ 46. (20.) Reflecting circle, by Jecker, of Paris, 11 inches in diameter, with one vernier reading to 15″.
„ 47. (21.) Box sextant; reflecting plane and level.
„ 48. (22.) Prismatic compass, by Troughton and Simms.
„ 49. (23.) Mountain barometer.
„ 50. (24.) Prismatic compass, by Thomas Jones, mounted with a cylindrical lens.
„ 51. (25.) Ordinary 4½-inch compass with needle.
„ 52. (26.) Dipping needle, by Robinson.
„ 53. (27.) Compass needle, mounted for variation.
„ 54. (28.) Magnetic intensity needle, by Meyerstein, of Göttingen; a strongly fitted brass box with heavy magnet; filar suspension.
„ 55. (29.) Box of magnetic apparatus.
„ 56. (30.) Hassler's reflecting circle, by Troughton; a 10½-inch reflecting and repeating circle, with stand and counterpoise, divided on platinum with two movable and two fixed indices; four verniers reading to 10″.
„ 57. (31.) Box sextant and glass plane, artificial horizon, by Troughton and Simms.
„ 58. (32.) Plane 2⅜ speculum, artificial horizon, and stand.
„ 59. (33.) 2½-inch circular level horizon, by Dollond.
„ 60. (34.) Artificial horizon, roof, and trough; the trough 8¼ by 4¼ inches.
„ 61. (35.) Set of drawing instruments, consisting of 6-inch circular protractor and common protractor, T-square; one beam compass.
„ 62. (36.) A pentagraph.
„ 63. (37.) A noddy.
„ 64. (38.) A small Galilean telescope, with object-glass of rock crystal.
„ 65. (39.) Five levels.
„ 66. (40.) 18-inch celestial globe.
„ 67. (41.) Varley stand for telescope.
„ 68. (42.) Thermometer.
„ 69. (43.) Telescope, with the object-glass of rock crystal.
„ 70. Portable equatoreal stand.
„ 71. Portable altazimuth tripod.
„ 72. Four polarimeters.
„ 74. Registering spectroscope, with one large prism.
„ 76. Two five-prism direct-vision spectroscopes.
„ 78. 9¼-inch silvered-glass reflector and stand, by Browning.
„ 79. Spectroscope.
„ 80. A small box, containing three square-headed Nicol's prisms; two Babinet's compensators; two double-

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image prisms; three Savarts; one positive eyepiece, with Nicol's prism; one dark wedge.

No. 81. A back-staff, or Davis' quadrant.
„ 82. A nocturnal, or star dial.
„ 83. An early non-achromatic telescope, of about 3 feet focal length, in an oak tube made in one piece. The words "Samuel Scatliffe, Londini, Fecit," are engraved on the draw-tube of the eyepiece.
„ 84. A Hollis observing chair.

Nos. 73,'75, and 77 have been removed from the list by order of the Council.

The following instruments are lent, during the pleasure of the Council, to the several parties undermentioned :—

No. 2. The *Owen* portable circle, No. 1, to Mr. Lecky.
„ 4. The *Beaufoy* transit instrument, to the Observatory, Kingston, Canada.
„ 12. The *Fuller* theodolite, to the Director of the Sydney Observatory.
„ 22. The *Matthew* equatoreal, to Mr. Brett.
„ 78. The 9¼-inch silvered-glass reflector, to Mr. Neison.
„ 81. *Davis'* quadrant, to Mr. Lecky.

From the *Sheepshanks* collection :—

„ 27. No. 1, to the Astronomer Royal.
„ 31. No. 5, to Mr. Birt.
„ 34. No. 8, to the Rev. Professor Pritchard.
„ 35, No. 9, to the Sydney Observatory.
„ 61. No. 35, 6-inch circular protractor, to Mr. Birt.
„ 67. No. 41, to the Rev. Professor Pritchard.
„ 69. No. 43, to Dr. Huggins.

The *Herschelian* 7-foot telescope and the *Cavendish* apparatus were lent to the Science and Art Department of the Committee of Council on Education in April last, for exhibition in the Special Loan Collection of Scientific Apparatus, at the South Kensington Museum. These instruments have now been returned to the Society, the Exhibition having been closed in December last.

The following is the list of missing instruments :—

No. 11. Universal quadrant, by Abraham Sharp.
„ 22. The *Reade* transit.
„ 32. *Sheepshanks* instrument, No. 6.
„ 64. „ „ „ 38.
„ 66. „ „ „ 40.
„ 68. „ „ „ 42.
„ 71. Portable altazimuth tripod.

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The Janson and Carrington Bequests.

During the past year the Treasurer has received the sum of two hundred pounds from the trustees of the estate of the late Mr. T. C. Janson, formerly a Fellow of our Society, who died in 1863. This legacy, which became payable on the death of his widow, has been added to the Lee Fund, in conformity with the wishes of the testator.

The interest which our late Fellow, Mr. R. C. Carrington, took in the welfare of our Society and in the promotion of practical astronomy, remained to the last, although in his later days ill-health prevented him in a great measure from continuing his active services in the cause of our science. By his will, drawn up a few months before his death, he bequeathed to the general fund of the Society the munificent legacy of 2,000*l.* Consolidated Annuities, free of duty, which was transferred by his representatives to the Society's Consols account in December last. Valued at 94 per cent., the market price on the day of transfer, the amount credited to the Society in the Treasurer's Report is 1,880*l.*

The Library.

On reference to the Treasurer's Report, the Fellows will perceive that the Council has devoted a considerable sum during the past year towards the improvement of the condition of the Library. The principal item of expenditure has been incurred on account of the large amount of binding required to be done for the orderly arrangement of the books, more especially of the serial publications. Hitherto, owing to the usual practice of not binding most of the serials, and to the confined space devoted to the Library at Somerset House, it was scarcely possible to preserve that order in the classification of subjects which ought to exist in such a valuable collection of astronomical and other scientific works as that belonging to the Society, and many of the advantages to be derived from a free circulation of the books were consequently lost to the Fellows. This was particularly felt in the case of the *Transactions* of foreign academies, and in the numerous scientific serials, which were often not easily found when required. On the removal of the Society to Burlington House, one of the early acts of the Council was the appointment of a Sub-Committee, with full authority to reorganise the Library, and to devise the necessary measures for placing it in an efficient condition. A liberal sum was at once voted by the Council to defray the expense of binding those works which immediately required it for their preservation, and further grants for the same purpose have been continued at intervals.

There is still a large amount of binding necessary before

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the full improvement in the Library arrangements will be seen, but a cursory glance over the various classified shelves is sufficient to exhibit the satisfactory transformation made in this important section of the Society's operations. The attention of the Sub-Committee has also been directed to the numerous *lacunæ* in the sets of serial publications, and fortunately they have succeeded in filling up many of them; but there is still much more to be done in this direction, as it is a notable fact that the library does not contain a perfect set of the *Astronomische Nachrichten*, and some other astronomical serials which are continually required for reference. A large number of valuable works have been added during the year from various sources. Besides the usual amount of presents received, the Library has been enriched by extensive purchases through the Turnor Fund, which had accumulated in February last to 164*l.*; by the munificent gift from the representative of our late honorary member, Miss Sheepshanks; by Lord Lindsay's presentation of four folio and ten quarto manuscript volumes of Mr. Carrington's observations of Sun-spots; by the Rev. F. Howlett's present of five large volumes of drawings of Sun-spots made by him in the course of the preceding seventeen years; and by Mrs. Selwyn's gift of a series of paper prints from the solar negatives of the Sun taken at Ely in the years 1863-1873, under the superintendence of the late Professor Selwyn.

As the result of the greater facilities afforded to the Fellows by the present arrangement of the Library, the Council are gratified in being able to report that the circulation of books during the past year is considerably in excess of that of former years.

The general rules and regulations for the management of the Library, drawn up by the Council in 1837, having become practically obsolete and unknown to the majority of the Fellows, new regulations have been prepared with great care in the interests both of the Society and of the Fellows. It is hoped that those who are in the habit of consulting the books in the Library will assist the Council in carrying these rules out in their strict integrity. For the convenience and information of the Fellows the new regulations are inserted below.

Regulations for the Library.

I. A book shall be kept in which shall be entered the title of every book borrowed, the name of the Fellow borrowing the same, and the date on which it is lent; and that an acknowledgment in writing shall be given at the time of borrowing any book from the Library; and on the return of such book the Assistant Secretary shall insert opposite to the entry the date on which the book has been returned, and give in writing an acknowledgment of its return. And if, on the return of such book, the Assistant Secretary shall perceive that it has sustained

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any damage during its loan, he shall make a note of the particulars, and report the same to the Library Committee.

II. No book shall be lent before its presentation to the Society shall have been announced at one of the ordinary meetings, unless the President or either of the Secretaries give permission to that effect.

III. A list of books and periodicals, which are not to be taken out of the Library without special permission from the Council, shall be placed in a conspicuous position in the Library.

IV. No Fellow shall be permitted to have more than ten volumes from the Library in his possession at any time without special permission from the Council.

V. In case any book borrowed from the Library shall be lost or damaged, the Fellow by whom it was borrowed shall be held responsible for the loss or damage; and, if belonging to any set, shall be held liable to make good the set to the satisfaction of the Council.

VI. All books shall be returned to the Library on or before the second Friday in November in each year. It shall be the duty of the Assistant Secretary, before the November meeting, to forward to all Fellows of the Society who, according to the entries in the book kept for that purpose, have any books belonging to the Society in their possession, a letter requesting that all such books be returned to the Society on or before the day of the November meeting.

VII. If any Fellow signify to the Assistant Secretary that he requires a book already taken out from the Library, it shall be the duty of the Assistant Secretary to make application to the Fellow who has borrowed it, and he shall return it, free of expense, within a month from the day on which application was made for it by the Assistant Secretary.

VIII. Every Fellow who shall have transgressed any of the above regulations shall be precluded from borrowing any book from the Library until he receives the special permission of the Council.

IX. No person who is not a Fellow of the Society shall be permitted to borrow any book, or to have access to the Library, without permission in writing from the President or one of the Secretaries.

Publications of the Society.

Volume XLI. of the *Memoirs*, containing collected accounts of physical observations of total eclipses of the Sun, which has now been upwards of five years in preparation, will, the Council have reason to hope, shortly be in the hands of the Fellows. A copy of a considerable portion of the volume which is already printed is placed in the Library, where it may be consulted by anyone interested in the subject. The volume will contain a large

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amount of classified information relating to solar eclipses observed down to 1874. It will extend to about 600 pages, and will be illustrated by woodcuts, and seventeen quarto plates, eight of which are devoted to the illustration, on a large scale, of the coronal structure visible in the photographs of the eclipse of December 11, 1871.

Nearly all the communications to the Society during the past year have been printed in the *Monthly Notices*, which still continue to be a favourite medium for the early dissemination of astronomical papers. Special attention may be directed to several valuable communications by the Astronomer Royal, the results of the extra-meridional work at the Royal Observatory. The most important of these contains the results of the recent observations of the displacement of the lines in the spectra of the stars and planets, with the object of determining the motions of certain stars and of *Venus* in the line of sight, and for the rotation of the Sun and *Jupiter*. The method employed by Dr. Huggins has been adopted in these observations with some modifications, and his conclusions have been borne out by the Greenwich observations. An interesting paper by Professor Langley on the measurement of the direct effect of Sun-spots on terrestrial climates, and one by Professor Newcomb, on a hitherto unnoticed apparent inequality in the longitude of the Moon, have been communicated to the Society and printed in the *Monthly Notices*. Many other important communications have been made to the Society, including papers by Mr. Knobel, Professor Harkness, Mr. Darwin, Mr. Knott, and others.

The volumes of the *Memoirs* and the separate numbers of the *Monthly Notices* as they appear are distributed to the principal public observatories and scientific libraries throughout the world at a considerable expense to the Society. Twenty-five copies of the *Monthly Notices* are also forwarded to the Hydrographer of the Admiralty for gratuitous distribution among the different surveying vessels. The Council trust that this liberality on the part of the Society in the interests of science, will ensure a corresponding interchange of all the scientific publications issued by our own Government, as well as by the various home and foreign institutions on our free distribution list.

It ought, however, to be remarked here that the usual complimentary copies of some Government publications, which for many years have been presented to the Society, will probably be discontinued in conformity with the terms of a recent Treasury Minute; and that if this be the case copies of such a work as the *Nautical Almanac* can in future be obtained for our Library only by purchase. The question is of slight importance if it referred merely to the *Nautical Almanac*, which is published at a small charge; but were this Minute carried out on the plea of economy, without some relaxation with respect to more expensive Government scientific publications, such as the *Greenwich Observations*,

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or the *Cape Observations*, it would be the greatest retrograde step in the relation of Government to science that has ever occurred.*

Some of the Fellows may probably be unaware that the *Memoirs* of the Society are presented gratuitously to them on application to the Assistant Secretary, at Burlington House, either by themselves or their accredited agents, within three years of the date of publication.

Obituary.

The Council regret that they have to record the loss by death of the following Fellows during the past year:—

Honorary Member:—Miss Anne Sheepshanks.

Fellows:—Rear-Admiral A. B. Becher.
C. H. H. Cheyne, Esq., M.A.
Lieutenant Cyril Corbet, R.N.
Thomas Dell, Esq.
Rev. John Edwards, M.A.
Charles Lambert, Esq.
Rev. Robert Middlemist, M.A.
Rear-Admiral H. C. Otter, C.B.
G. W. Roberts, Esq.
Chevalier François de Rosaz.
Lieut-Colonel Alexander Strange, F.R.S.
Andrew Yeates, Esq.

Our late Honorary Member, Miss Anne Sheepshanks, who died at an advanced age a few days before the last anniversary meeting, was one of the many patrons of our science whose memory will remain associated with the history of astronomy in the nineteenth century. The sister and companion of the late Rev. Richard Sheepshanks, of whom she was the senior by five years, she shared the interest which he always took in the progress of astronomy, and especially in the proceedings of this Society, in the administration of which he had laboured so faithfully and so successfully to within a short period of his death. Through this admiration of her brother's love for astronomical work, and also as a record of her own affection for his memory, Miss Sheepshanks determined to devote a considerable portion of her property for the promotion of the study of his favourite

* It will be gratifying to the Fellows to be informed that since this Report was read at the Annual Meeting, the Astronomer Royal has received an official communication from the Secretary of the Treasury, dated February 9, 1877, stating that the Stationery Office has been authorised to hand over the whole impression of the *Greenwich Observations* every year for gratuitous distribution according to the discretion of the Astronomer Royal, subject only to an annual report of the details of the distribution being submitted to the Treasury.—E. Dunkin.

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science in the University of Cambridge. To carry out her views in the most advantageous manner, she sought the advice and assistance of some of her brother's most intimate scientific friends, by whom she was guided in her decision as to the appropriation of her intended gift. She ultimately resolved to transfer the munificent donation of 10,000*l.* Consols into the joint names of the Master, Fellows, and Scholars of Trinity College and Mr. (now Sir George B.) Airy, the interest of which was to be devoted to the advancement of astronomical and kindred sciences in the University. A Grace, accepting the gift, was passed by the Senate at the Congregation held on the 9th of December, 1858. It was finally recommended by Dr. Whewell, Master of Trinity College, and Mr. Airy, on the part of Miss Sheepshanks, and agreed to by the Vice-Chancellor and other University authorities, that one-sixth part of the amount, producing 50*l.* per annum, should be specially devoted to the foundation of an astronomical scholarship at Trinity College, to be named the "Sheepshanks Exhibition," and that it should be open to the undergraduates of any of the colleges, the exhibition being awarded, after examination, to the candidate best versed in theoretical and practical astronomy. Bearing in mind the long connection of Mr. Sheepshanks with Trinity College as one of its Fellows, it was considered that the endowment of this permanent astronomical exhibition would be a most appropriate memorial to him in his own University, and at the same time be subject to the care of his own College. Though the Sheepshanks Exhibition is open to the whole University, it has been practically confined to Trinity College, and it has been generally given to one of its undergraduates, who subsequently attained the high position of senior wrangler. The first examination took place in 1859. The exhibition is tenable for three years, on condition that the holder shall keep, by residence, every University term during that time. The interest of the remaining five-sixths of the donation has been reserved to be applied, as required, for the promotion of astronomy, terrestrial magnetism, and meteorology, in connection with the Cambridge Observatory, either in the payment of the stipends of the assistants and computers, or in the purchase of instruments.

In 1860, an additional sum of 2,000*l.* was placed by Miss Sheepshanks into the hands of Mr. Airy to provide a fund for the purchase of a new transit-circle for the Cambridge Observatory. Circumstances having prevented the immediate erection of the instrument, Mr. Airy, with the donor's consent, transferred the amount, with its accumulated interest, to the Vice-Chancellor in the beginning of 1863, a Grace having passed the Senate for its acceptance on the 12th of March of that year. From this second act of beneficence on the part of Miss Sheepshanks, the Cambridge Observatory has been enriched by the excellent meridian-circle, which was constructed by Mr. James Simms, and mounted in the latter part of 1870. It is a first-class meridional instrument, and compares favourably with those

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at other public observatories. It is furnished with an object-glass of eight inches aperture, and is provided with two graduated circles of three feet in diameter, one fixed and the other movable. It has also two collimating telescopes, as in the Greenwich transit-circle, each of six inches aperture, which can be directed on each other through the central cube of the instrument. In its construction generally, advantage has been taken of many recent improvements in this class of instruments.

Miss Sheepshanks, after the sudden death of her brother in 1855, lived a very retired life at her residence at Reading, where she died on February 8, 1876, aged eighty-six years. The Fellows of the Society are greatly indebted to her representative, the Rev. Thomas Sheepshanks, for his spontaneous and valuable donation to our Library of 161 separate works, consisting of 192 volumes, forming a portion of the library of the late Rev. Richard Sheepshanks. Many of these works are extremely rare, and of considerable pecuniary value. The title of each work may be found in the list of presents attached to the supplementary number of Vol. XXXVI. of the *Monthly Notices*. A box containing a large number of letters on scientific subjects, received by Mr. Sheepshanks from several distinguished astronomers, together with other correspondence on some controversial matters, has also been presented to the Society, at the request of the Secretaries. These have been sorted and arranged, and it is the intention of the Council to have them bound in an orderly manner for easy reference. E. D.

Rear-Admiral Alexander Bridport Becher was the son of Captain A. Becher, R.N., an officer of high scientific attainments. He was born in the year 1796. He entered the Royal Naval College in 1810, and in November 1812 he joined the *Barham*, 74, Captain Spanger, with whom he served as master's mate. This ship was attached to the Channel Fleet, then engaged in the blockade of Brest, from which it was detached to take a large convoy of ships to and from the West Indies. After serving a short time in the *Cordelia*, a 10-gun brig, in the Channel, he joined Commodore Owen for active service on the lakes of Canada during the American War; but on peace taking place soon afterwards, he was transferred to the surveying party under the command of Captain W. F. Owen, brother of the Commodore. This officer was in 1815 commissioned to survey the Canadian Lakes and the River St. Lawrence. Young Becher entered heartily into this work, for which he was exactly suited, the survey having been carried on by a large party afloat in summer, and on the ice in winter, and he has remarked that "he took his full share of the ice work, and had as many ducking from breaking through the ice as anyone of the party." In 1818 he joined the *Superb*, 74, at Plymouth, and in September of that year the *Leven*, Captain Bartholomew, with

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whom he spent twenty months on scientific service in the Atlantic, determining the longitude of Funchal, rock hunting, and in surveying the Azores, a part of the African coast, and some of the Cape Verd islands. In 1820 he was appointed to the *Conway*, 26, Captain Basil Hall, on the South American station; and in May 1822 he received his first promotion, as Lieutenant. Between March and December 1839, he served as First Lieutenant in the *Fairy*, surveying vessel, which in the following year foundered during a severe gale in the North Sea, with the loss of Captain Hewett and all his crew. He was made a Commander in 1841, and his last service afloat was undertaken in 1848, to qualify himself for promotion to the next step of rank. Captain Becher thus completed his necessary period of active service as Commander of a surveying vessel on the coast of Scotland. In 1856, he attained the rank of Captain on the Reserved list, and about a year before his death that of Retired Rear-Admiral.

In 1837, Lieutenant Becher communicated to the Society a description of his well-known pendulum artificial horizon, to be attached to a sextant or quadrant for the purpose of observing altitudes by day or night at sea. The special object of the invention was to provide a means of making accurate sextant observations when the real horizon is invisible, either from haze, fog, or other causes. This practical instrument, the result of Lieutenant Becher's nautical skill, requires careful management, and when used by competent observers, it has been proved to be a valuable aid to the nautical astronomer. This extra care required has prevented it from becoming generally adopted in the Service; but the Admiralty acknowledged the ingenuity of the inventor by granting him a moderate pecuniary reward.

In 1823, soon after his return from the South American station, an opportunity was afforded him of employment at the Hydrographic Office. Owing to the recent death of the Hydrographer, an officer was required to arrange and methodise, for easy reference, all the numerous and varied documents preserved in that office, consisting of charts, maps, and plans of every kind, both printed and in manuscript. This entailed the compilation of a general and alphabetical catalogue, with a methodical geographical arrangement of the whole of the papers. For such a work Lieutenant Becher, who happened to be visiting the Admiralty with the object of obtaining an appointment in another ship, appeared to be just the person required; and as he had been accustomed to maritime surveying, and was well acquainted with the construction of charts, this duty was offered to him by the new Hydrographer. He very gladly accepted the laborious task; and his youth and vigour, together with a natural love for the seaman's chart, and a zeal that would not yield to any amount of work, carried him on to the completion of the catalogue, which required three years for its performance. The number of separate entries exceeded 50,000.

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Lieutenant Becher's experience of marine surveying, and his general knowledge of hydrographic work, increased in no small degree by his recent duties, led to his permanent appointment as assistant in the Hydrographic Office, in which he remained till his retirement on superannuation in 1865. Twice during this long service he was permitted to go afloat to qualify for rank; but his Admiralty employment was, in each case, kept open for him till his return. While holding the official rank of Chief Assistant to the Hydrographer, Captain Becher also acted as secretary to the Board of Visitors of the Royal Observatory. At the annual visitation on the first Saturday in June of each year, it was his invariable custom to give an official character to his journey from the Admiralty, and many will recollect the pleasant hour passed in his company from Whitehall to Greenwich in the Admiralty barge. He became a Fellow of the Royal Astronomical Society in 1830, and has served on the Council.

Captain Becher took a great personal interest in the success of the *Nautical Magazine*, of which he was the editor from its commencement in 1832 to 1871. It was his chief endeavour to make it a favourite among nautical men, in which they might find hydrographical notices of the discoveries of rocks and shoals, the establishment of light-houses or buoys, and of all matters of interest relating to the Navy or the Mercantile Marine. It was, indeed, a child of his own. He was its guiding spirit during the forty years of his editorship, and he succeeded in obtaining for it a considerable professional reputation, its pages having been always open to the advocacy of any cause which had for its object the promotion of the interests of naval officers, or the amelioration of the condition of our seamen. Many of the most important papers in the Magazine were from his own pen, including translations of foreign hydrographical notices. Captain Becher was often occupied in his leisure hours with other literary work; and in his *Landfall of Columbus* he has apparently succeeded, after much labour, in tracing the actual progress of Columbus among the islands discovered by that great navigator on his way to Cuba.

During the last few years of Admiral Becher's life, failing health compelled him to relinquish all public work; and he lived in retirement, respected by the profession as a kind friend, a zealous and hard-working officer, and a valuable public servant. His promotion to the rank of Rear-Admiral was gratifying to him in his old age, though he did not long enjoy the honour. He died at his residence in London on the 15th of February, 1876, in his eightieth year. His daughter is the wife of Dr. Ellicott, Bishop of Gloucester and Bristol. E. D.

Charles Hartwell Horne Cheyne, M.A., was the eldest son of the Rev. Charles Cheyne, many years Second Master at Christ's Hospital, and maternal grandson of the Rev. T. Hartwell

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Horne, the well-known Commentator. He was born on the 1st of May, 1838, and was educated at Merchant Taylors' School, where he continued till he entered St. John's College, Cambridge, in October 1857. He was elected to a foundation scholarship at that college in June 1859, and obtained the B.A. degree in January 1861, as eighteenth wrangler in the Mathematical Tripos.

Soon after taking his degree, Mr. Cheyne contributed to the *Quarterly Journal of Mathematics*, and to the *Messenger of Mathematics*, three original articles on the variation of the Elements in the Planetary Theory. These were followed in October 1862 by the publication of his *Elementary Treatise on the Planetary Theory*, which includes his own investigations, besides all that is important to the student from the works of former writers on the subject. This systematic treatise has become the recognised text-book in Cambridge, and has reached a second edition. Subsequently, in September 1867, Mr. Cheyne published an essay on the *Earth's Motion of Rotation*. In the first part of this work he developed the analogy between the processes for obtaining formulæ for the variation of the elements in the two problems of the Earth's motions of translation and rotation. The methods of investigation are remarkably original, and the subject was presented, for the first time, to English students. The second part contains the application to the questions of Precession and Nutation, and the stability of the Earth's rotation.

In March 1863, Mr. Cheyne was appointed Second Mathematical Master of Westminster School, and in 1864 he proceeded to the M.A. degree. While at Westminster, he published, in conjunction with his colleague, the Rev. C. A. Jones, a collection of *Algebraical Exercises*, progressively arranged, a work which has passed through several editions, and is largely used in our Public Schools. In June 1868, he was elected a Fellow of our Society, and he was a frequent attendant at our meetings. His singularly quiet and unobtrusive disposition prevented him from taking any active part in the proceedings of the Society, for which he was so well qualified; and the pressure of his school duties legitimately interfered with any desire he may have entertained for continuing his astronomical researches.

For the last two years Mr. Cheyne had been in failing health, which ultimately compelled him to resign his mastership in the school. He, however, retained his position there till only a few weeks before his death. He retired to the milder climate of Torquay, where it was hoped that his health would be at least partially restored; but the change was made too late, and he sank from exhaustion within a fortnight of his departure from Westminster, on the 1st of January 1877, at the early age of thirty-eight.

Lieutenant Cyril Corbet, R.N., was born at Shrewsbury on the 24th of March 1850. He was the youngest of ten children

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of Mr. Philip Corbet. At the early age of seven he was sent to Christ's Hospital School, and at twelve he competed for and gained the first cadetship offered to the school by the Board of Admiralty. He entered the Royal Naval College at Portsmouth in December 1862, becoming a midshipman in March 1864, when he joined the *Prince Consort*, Captain Willes. In December 1869, while serving in the *Pallas*, he was made a Sub-Lieutenant, and in the same year he gained the "Beaufort Testimonial," awarded to the officer who obtained the highest number of marks in the examinations of the year. In March 1870, he was appointed to the *Zealous*, flag-ship in the Pacific, and on the 30th of December 1872, he was gazetted Lieutenant. While serving in this ship his natural geniality and kindness of disposition made him a great favourite with both officers and men. The record of many of the incidents of their three years' cruise along the American shores and islands in the Pacific has appeared in *Our Journal in the Pacific*, to which Lieutenant Corbet made several contributions, more especially the chapter relating to an interesting adventure in the wilds of British Columbia.

On the return of the *Zealous* to England in 1873, Lieutenant Corbet was requested by the Admiralty to join a select number of officers who had volunteered for service in connection with the observation of the Transit of *Venus* in December of the following year. He most willingly accepted this duty, and, in consequence, he proceeded to the Royal Observatory to receive the necessary instruction in the use of the various instruments required for the observations. Into this preliminary work he entered with the utmost energy and zeal, and soon became practically conversant with the methods of making and reducing the observations. His steady attention to his duties at the Observatory was the cause of his selection for the important post of chief observer at the second station in Kerguelen Island. For a position of trust of this nature, his high principle, and earnest, thoughtful, and devoted character peculiarly fitted him. He was fully convinced of the importance of this charge, and during his leisure hours at the Royal Naval College at Greenwich he was ever improving his acquaintance with the theory of the observations which he would be required to make at his distant station.

In addition to the appointment as chief observer at the second Kerguelen Station, Lieutenant Corbet was also entrusted with the care of the chronometers especially employed for determining the difference of longitude between the Cape Observatory and Kerguelen, and for the connection of the various stations in the South Indian Ocean. Sailing from England for the Cape of Good Hope in May 1874, in charge of the first detachment of observers, he was ever at work throughout the voyage, as well as during his stay at the Cape, perfecting himself in calculations and observations, or superintending the

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necessary preparations in the dockyard at Simons Bay. He appeared to throw his whole soul into the duties he had undertaken, and his persevering and cheerful labour was a great encouragement to others, as well as being most valuable in itself.

On the day of the transit he was fortunate in obtaining an accurate observation of the first internal contact, the faint light streak around *Venus* being in perfect contact with the Sun's limb; but clouds prevented observations at the egress. The first two months in Kerguelen were devoted exclusively to the necessary preparations for the important observations on December 8; but during the remainder of his stay in the island he spent many nights in taking his turn at the transit or alt-azimuth instruments, while the chronometer-runs and longitude calculations well filled up his days. Even on his homeward journey he continued his work, and it was only when he received at Bombay the sad intelligence of the death of his mother, that he was at last forced to discontinue his calculations and to return in all haste to England.

In June 1875, Lieutenant Corbet was appointed to the *Sirius*, commissioned for service on the West Coast of Africa. Having been sent to visit the Governor of the Colony at Loando, he was struck down on the following day by coast fever. He was at once taken to St. Helena, where he died, soon after reaching that island, on the 17th of February 1876. Thus suddenly closed a career full of promise, before he had completed his twenty-sixth year. Honoured and beloved by his fellow-officers and men, they have placed a monument over his remains, as a tribute to his memory, in the cemetery of St. Helena.

Lieutenant Corbet was elected a Fellow of the Royal Astronomical Society on December 10, 1875, little more than two months before his decease. His connection with us was, therefore, of very short duration. The announcement of his premature and sudden death was deeply deplored by his many friends. The simple thoroughness and kindliness of his nature caused him to be highly esteemed and beloved by others than his immediate relations and private acquaintances, especially by those with whom he had been officially associated in the Navy, or in connection with the Transit of *Venus* operations both at Greenwich and Kerguelen.

The Rev. JOHN EDWARDS, M.A., of St. Aidan's College, Birkenhead, was ordained by the Archbishop of York in 1856. He was appointed to the rectory of Bradford-cum-Beswick, Manchester, in 1859, which he held till his death. At an early age he became much interested in astronomical science, and, in his later years, became thoroughly versed in its history and standard writers. Frequently he devoted the little leisure at his disposal to astronomical observation, which was always a pleasure to him. Mr. Edwards was a ready and eloquent speaker, and

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occasionally he delivered a series of astronomical lectures, remarkable for their simplicity and comprehensiveness. He was elected a Fellow of the Royal Astronomical Society on November 12, 1869. His literary attainments were highly respectable. He had a well cultivated mind, and was intimately acquainted with biblical literature in general, with ecclesiastical history, and with the various controversies of the Church, of all ages. As a parochial clergyman, Mr. Edwards had few equals in the ability of his ministrations, the ardour of his zeal, and the abundance of his labours. He possessed naturally great geniality of spirit, and was singularly affectionate in disposition. His death has therefore been deeply regretted by his clerical brethren, by his personal friends, and by his parishioners. Mr. Edwards died at his rectory at Bradford-cum-Beswick on the 30th of January 1876, at the age of fifty-eight.

The Rev. ROBERT MIDDLEMIST, M.A., was born on February 29, 1808, and was descended from a respectable Northumberland family. He was educated principally by his relative, Mr. Gourley, who was at that time Head Master of the Grammar Schools at Morpeth and Hexham. When quite a youth, he was in the habit of answering mathematical questions given in the *Lady's Diary*, by which means he soon became known by name to some of the leading mathematicians of the day, who were also contributors to the mathematical section of the *Diary*. By one of these, but an entire stranger to him, he was recommended, in 1831, to Lieutenant Stratford, the Superintendent of the *Nautical Almanac*, as a highly-qualified computer and a good mathematician. This led to his engagement as one of several young computers required to perform the calculations of the new and enlarged edition of the *Nautical Almanac* on the greatly improved plan adopted in November 1830 by a Committee appointed by the Council of the Astronomical Society, and afterwards approved by the Lords Commissioners of the Admiralty. Previous to this, the computations of the *Nautical Almanac* were made in different parts of the country, three of the computers residing in Cornwall, and others at Greenwich, Ludlow, Tideswell, &c. Two only of the old computers, Mr. William Dunkin, of Truro, and Mr. Henry Jenkins, of Greenwich, were retained for service in the newly-established office. Mr. Middlemist was one of the first appointed on the staff, and he was therefore engaged on the *Almanac* for 1834, the first of the new series. He was much trusted by Lieutenant Stratford, who had great confidence in his abilities, and he was selected to make the careful comparison and examination of the duplicate calculations; a duty he performed with such patience and fidelity, that Lieutenant Stratford, in the Preface of the *Nautical Almanac* for 1834, remarked that it was impossible to appreciate too highly the manner with which

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he executed this most tedious task. Mr. Middlemist joined our Society on March 14, 1834.

After having served for some time as mathematical master in the Royal Naval School, Mr. Middlemist entered Christ's College, Cambridge, in 1838, as an undergraduate. He became a scholar of his college, and graduated as B.A. in January 1842, being 27th Wrangler. For a time he acted as curate to the Rev. J. E. Gretton, of Stamford; but in 1845 he received the important appointment of senior assistant mathematical master in Harrow School, an office which he retained till his death. He was also vicar of Little Linford, Bucks. Though an occasional attendant at our meetings, Mr. Middlemist does not appear of late years to have interested himself much in astronomy, and he has never been a contributor to the *Proceedings* of this Society. While on a visit to his sister at Ramsgate, he was suddenly attacked with inflammation of the lungs, and died there eight days afterwards, on the 11th of January 1877, in the sixty-ninth year of his age. He has left a widow and seven children—six sons and one daughter. E. D.

Rear-Admiral Henry Charles Otter, C.B., was born in the year 1807. At the age of fifteen he entered the Navy as a cadet, and obtained his first commission as Lieutenant in 1831. From August 1833 to the end of 1835, he served as a supernumerary Lieutenant in the *Ocean*, 80, and *Howe*, 120, at Sheerness. At this time he gave many indications of his talents as a scientific officer, and much of his leisure time was occupied in perfecting himself in astronomical observing, especially with those instruments which are practically used for surveying purposes. His acquaintance with the principal nautical astronomers, added to his personal attachment to the observing branch of our science, induced him to become a Fellow of the Royal Astronomical Society, to which he was elected on the 11th of November 1842. In March 1844, Lieutenant Otter was appointed to the command of the *Sparrow*, surveying vessel on the coast of Scotland, and thus commenced that active career as a nautical surveyor under the Hydrographic Office, which he continued for a long number of years, commanding in succession the *Avon*, *Porcupine*, *Shamrock*, and other surveying vessels.

Admiral Otter, when a midshipman, had the satisfaction of performing a most gallant act, as by his heroic exertions he was the means of saving the lives of a boat's crew while in extreme danger, and so lately as 1845 he jumped overboard from the *Sparrow* for the purpose of affording assistance to some of his crew who had been capsized. Most of his time till his retirement was spent afloat in the performance of his surveying duties. His successive promotions were to Commander on August 26, 1844; to Captain on September 8, 1854; and to Retired Rear-Admiral on April 1, 1870. He died at Clare Park, Hants, on the 26th of March 1876, aged sixty-eight. E. D.

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George Walter Roberts was the third and youngest son of the late Mr. Henry Roberts, of Crow Trees, Gomersal, near Leeds, where he was born on February 9, 1846. From early life he took an interest in astronomy, and about the year 1867 he formed a plan of making a series of planetary delineations with a 12-inch reflector, but he was prevented from carrying out his wishes by the wanton destruction of his instrument by a party of drunken roughs. He, however, shortly afterwards erected a new Observatory, which he furnished with a transit instrument, and an 8-inch achromatic telescope, by Wray, equatoreally mounted. With this instrument he was accustomed to devote many of his leisure hours to astronomical work, though he was not usually in the habit of publishing his observations. On March 26, 1873, he observed the fourth satellite of *Jupiter* during its transit across the planet's disk as a very intensely black spot, the particulars of the phenomenon being recorded in Vol. XXXIII. of the *Monthly Notices*. A recent change of residence, combined with increasing ill-health, compelled him to relinquish all scientific work. Mr. Roberts, who joined our Society in March 1872, was ever willing to give his assistance in spreading an interest in astronomy in his neighbourhood; and his cultured mind and genial disposition brought him a large circle of personal friends, by whom his loss will be severely felt. He died at his residence in Leeds, on January 19, 1877, in the thirty-first year of his age, leaving a widow and two daughters.

The Chevalier François de Rosaz was a native of Savoy, but the latter part of his life has been spent in England. He was the only son of a gentleman of some position in his native country, and was originally educated for the medical profession; but his tastes inclined to law rather than to medicine, and he eventually became, during the reign of Louis Philippe, a successful advocate in the legal Courts of Paris. Having been a great supporter of the Orleans dynasty, he resolved to leave France after the Revolution, which resulted in his retirement altogether from his profession. He now settled permanently in England, residing alternately in London and at Brighton, where he continued to lead a most active life, devoting nearly his whole time to philanthropic objects, even to within a short period of his death. He was the founder or supporter of seven distinct charities at Montmelian, his native town, and nearly the whole of his large property is ultimately to be reserved for their permanent benefit, and for the foundation of similar charitable institutions at Brighton. M. de Rosaz was naturally a scientific man, and in his leisure hours he was in the habit of making himself acquainted with the practical use of many valuable instruments which he possessed. He was particularly fond of astronomy, and on his election less than three years ago, he expressed to one of the Secretaries his gratification at being admitted in his old

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age a Fellow of the Society. His astronomical instruments, which have been the means of affording instruction to many of his friends, are bequeathed to the Museum at Brighton. His death took place rather suddenly in London, on the 21st of September 1876, in his seventy-sixth year. E. D.

Lieutenant-Colonel ALEXANDER STRANGE, F.R.S., was born at Westminster on the 27th of April 1818, and was the fourth son of Sir Thomas Strange. He received his principal education at Harrow. In 1834, at the early age of sixteen, he was appointed to the 7th Regiment of Madras Light Cavalry, and soon after left England for India, where he passed a continued service of twenty-six years, a large portion of which was in connection with the Great Trigonometrical Survey, then under the superintendence of Captain (now Major-General Sir Andrew) Waugh. His abilities, which were of the highest order, attracted the attention of several scientific officers, from whom he received not only valuable counsel, but also practical instruction in the use of astronomical and surveying instruments. His mechanical skill, so advantageously utilised in after years in his designs for improved geodetical instruments, made it obvious to the military authorities that scientific employment was his natural avocation, and that his talents would prove more advantageous to the service if devoted to the scientific branch of the army than if they were permitted to remain dormant in the routine performance of his regimental duty. For a time he studied at the Magnetic and Meteorological Observatory at Simla, then under the charge of Major (now Major-General) Boileau, F.R.S., and in 1847 he received the appointment of second assistant in the Great Trigonometrical Survey, the duties of which exactly corresponded with his taste for astronomical observing. He thus obtained a full scope for the exercise of those peculiar talents for scientific work which he had exhibited from the time of his entry into the service.

Soon after the acquisition of Scinde and the Punjab, the Surveyor-General considered it of great importance that the newly-acquired territory should be connected with the "Great Arc Series" of triangulations, having the Dehra Doon base at the north, and the Sironj base at the south. From the base at Dehra Doon a north-western series was also to be extended to near Attock, where a new base was to be measured. It was likewise resolved that the line of the "Calcutta Longitudinal Series" should be extended from the Sironj base to Kurrachee, to be named the "Great Longitudinal Series," forming, with extensions to other districts of the Indian territory, a perfect gridiron of triangulations. The western section of this operation was commenced at the end of 1848 by Captain Renny (afterwards Major Renny-Tailyour), assisted by Captain Strange and others, commencing from the Sironj base. In the following year, Captain Renny retired from the Survey, after having executed about

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eighty miles of triangulation. He was succeeded by Captain Strange, under whose superintendence this important geodetical work was brought to a successful termination. He was assisted by Lieutenant (now Colonel) Tennant, R.E., and a civilian staff. This triangulation was carried over the rugged range of the Aravulli mountains, then across the great Thurr, or desert, to the north of the Runn of Cutch. After crossing the valley of the Indus, the party reached Kurrachee in April 1853, after five seasons of very severe work. Some idea may be formed of the magnitude of this great triangulation by a reference to the actual distances between the commencing and terminal stations. It has been calculated that the series was 668 miles in length, and consisted of 173 principal triangles, covering an area of 20,323 miles. This is also the first example of a true desert being successfully traversed by a great triangulation.

The remarkable energy displayed by Captain Strange in the management of this great surveying work reflected on him the highest credit, and the manner in which the triangulation was effected was fully to the satisfaction of the Surveyor-General. How these field duties were performed by the party, and what obstacles they had to encounter, is thus related by Mr. Clements R. Markham, F.R.S., in his *Memoir on the Indian Surveys*, a work to which the writer is indebted for several of the facts contained in this notice. "The great difficulty, peculiar to this series, was the crossing of the desert. No geodesical operation of the first order had, at that time, ever been conducted in a desert, and experience was therefore totally at fault as to the probable obstacles to be encountered. Stations had to be selected, in the first instance, by an advanced party. At each station a masonry platform had to be erected in a country entirely composed of sand, and destitute of building materials. After this had been accomplished, the main party engaged in taking the final observations, numbering two hundred men, had to be maintained in the desert during a whole season. The desert furnished only three things useful to man or beast, namely, grass, immediately after the rainy season; limited supplies of milk; and brackish, or, more correctly, salt water in deep wells, scattered at wide intervals. The arrangements therefore involved the supply of provisions of every description for two hundred men during several months. * * * Captain Strange's party reached the borders of Scinde, and commenced operations on the 8th of December 1852. The first station was Chortlee, where it was necessary to observe from a tower thirty-seven feet high, the side being twenty-two miles long, and crossed by the Indus. The view was obstructed by a dense *babool* jungle, intersected in many places by sheets of water. It was a tedious task to clear the line, and then it was long before the signal could be made out at the other station of Helaya, twenty-two miles away. After a wearisome detention of twenty-five days, and much painful straining of the eyes, occasional faint glimpses of Helaya were caught, and at length the angle was

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satisfactorily observed. At the next station of Kanad there were fresh misfortunes. The tower, thirty-nine feet high, began to emit a cracking sound towards evening, and luckily the great theodolite had not been placed, when one of the angles fell in. At another place the great theodolite narrowly escaped destruction from a hurricane, and was rescued by the desperate efforts of its guardians, amidst the war of the tempest, in a night of inky darkness. Such are the sort of harassing difficulties and delays which form the daily life of the surveyor, but which are ever cheerfully faced and overcome. Captain Strange and his party had their full share; but at length their work was completed, and the last angle of the series was taken at Muggur Peer station on the 22nd of April 1853."

From this time Captain Strange was employed continuously on surveying work, and in June 1854 he was promoted to the rank of Brevet-Major. In the winter of 1853–4 he assisted in the measurement of the base-line at Attock, the place previously selected by the Surveyor-General as the site for the northern base, in company with other chief officers in the Survey. At the conclusion of the measurement, the apparatus was transported to Kurrachee, the selected site for the southern base operations. The principal charge of this second measurement was entrusted to Major Strange, under the general superintendence of Colonel Waugh, the Surveyor-General, who joined the party at Kurrachee on the 6th of December 1854, on which day the measurement was commenced, having been finally completed on the 20th of the following month.

On the retirement, in 1855, of Mr. Peyton from the superintendence of the "Eastern Coast Series," Major Strange was appointed his successor. The surveying work of this "Series" consisted in carrying a chain of triangles over the eastern coast of the Peninsula from Calcutta to Madras, and it proved to be one of the most difficult portions of the whole Survey, owing principally to the unhealthy climate, the general unfavourable state of the atmosphere, an inaccessible country, and, what probably gave the most anxiety, an inefficient native staff. The work was frequently interrupted by one or other of the party being laid low with jungle fever, which produces a great debility, and depression both of the mental and physical powers. In 1857 Major Strange had a very severe attack, which compelled him to seek a more bracing climate for the restoration of his health, and for a time he resided at the Neilgherry Hills. On his recovery, he returned to his duties, and further progress was made in the survey; but on his promotion in 1860 to the rank of Regimental Major, and in accordance with the usual regulations of the Service, he was obliged to retire from the superintendence of the Series, and also from the Survey, after a connection of thirteen years with the Department. He was succeeded in the charge of the "Eastern Coast Series" by the late Captain Basevi. In 1861 Major Strange returned to England, and

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soon after retired from the Army with the rank of Lieutenant-Colonel.

The practical experience gained by Colonel Strange during his various surveying operations, naturally rendered his opinion, in connection with the construction of scientific instruments, of great value; for his proved mechanical skill, and his practical knowledge of the use of mathematical, surveying, and astronomical instruments, was equalled by few men in this country. In 1862, the Indian Government, desirous of securing the advantages of such a great experience in instrumental matters, entrusted to Colonel Strange the task of designing and of superintending the construction of a series of massive and standard instruments, of the first order, for the use of the Great Trigonometrical Survey of India, and in 1863 he received the appointment of Inspector of scientific instruments; his duty to consist of examining and testing every instrument purchased in England, and destined for public service in India. For this purpose an observatory was erected at the warehouse of the Store Department of the India Office, in the Belvedere Road, Lambeth. The class of instruments usually inspected under Colonel Strange's personal superintendence, consisted principally of those employed in surveying operations, including telescopes, sextants, theodolites, levelling instruments, barometers, thermometers, and almost every kind of mathematical and drawing instruments. Nearly one hundred different kinds have been examined yearly, and in that time as many as 7,000 instruments, large and small, have passed through his hands for service.

But the principal instrumental work which occupied the attention of Colonel Strange, was that required for the completion of the large surveying instruments ordered for the Indian Survey. These consisted of two zenith-sectors and a great theodolite, by Troughton and Simms; two five-feet transit instruments, and two smaller ones, by Cooke; two twelve-inch vertical transit instruments, by Repsold; two galvanic chronographs for the registration of transit observations, by Secretan; and three astronomical clocks, by Frodsham. The consideration of the best means of construction, of the metal to be employed, the preparation of the working drawings, and the preliminary trials of the different instruments, absorbed a considerable portion of the time devoted by Colonel Strange to his official work. All this was, however, performed without neglecting the general inspection of the smaller class of instruments. The working drawings of the great theodolite were completed as early as May 1862, embracing the most minute details in nine large sheets, accompanied by a voluminous specification.

Colonel Strange joined our Society on the 12th of April 1861, and he was an active member of our Council, and Foreign Secretary, from 1863 to 1873. He was an ardent lover of science for its own sake; and from the date of his return from India, he has been associated in the management of several Societies,

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whose objects coincided with his own peculiar habits of thought. He became a Fellow of the Royal Society on the 2nd of June 1864, and was a member of the Council from 1867 to 1869. He was much interested in the Annual Meetings of the British Association, and was a frequent speaker and contributor in Section A. He was also connected with the Meteorological Society and the Society of Arts. Though Colonel Strange was so much occupied with his official work, he had sufficient leisure to enter heartily into any scheme which had for its object the advancement of any branch of science. Most of his communications to our Society have a highly practical value, and relate chiefly to improved methods of instrumental construction. They exhibit evidence of his great technical knowledge of the optician and engineer's workshops, and they all add to his reputation as a mechanician of the highest order. The following are the titles of his principal papers contained in our *Memoirs* and *Monthly Notices*:—"On testing the Vertical Axis of Altazimuth Instruments;" "On a Direct Method of Testing and Adjusting the Equipoise of Altazimuth Instruments;" "On a Proposed Isolated Flange for Conical Axes;" "On Aluminium Bronze as a Material for the Construction of Astronomical and other Philosophical Instruments;" "On a Zenith Sector for the use of the Trigonometrical Survey of India," &c. In his observatory at Lambeth, Colonel Strange was frequently occupied in purely astronomical work, principally with the object of proving the capabilities of his instruments. In consequence of the peculiar, and, to some extent, private, nature of the observations, very few have been published, although some might have been, to the advantage of astronomy. He was known to have made a careful determination of the latitude of his observatory with one of the instruments made for the Indian Survey, and the observations, if judged by the separate results shown by him to the writer, must have been of great excellence.

Colonel Strange was requested to perform the duties of a juror in the International Exhibition of 1862. He undertook this important office with much pleasure, as it was one in which he could bring his practical knowledge to bear on the peculiarities in the construction of the numerous scientific instruments which would come under examination. He served also a similar office in the Paris International Exhibition of 1867. He had very decided opinions on the question of Government endowment of scientific research, but though they were considered by many as somewhat impracticable, yet very few can doubt his own great sincerity in the soundness of the views entertained by him on the subject. The appointment by her Majesty of the "Royal Commission on Scientific Instruction and the Advancement of Science," of which the Duke of Devonshire was Chairman, was, in a great measure, the result of his persistent advocacy of the necessity for increased Government aid for the promotion of scientific research; and, before his

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death, he had the satisfaction of knowing that many of his proposals were adopted by the Commission, and recommended to the Government for their consideration.

The health of Colonel Strange was not good for several months before the end came, but the announcement of his death was unexpected, and was received with deep regret by a large circle of scientific friends. He died at the residence of his niece in Onslow Square, London, on the 9th of March 1876, at the comparatively early age of fifty-seven. E. D.

Andrew Yeates was the second son of Samuel Yeates, a well-known mathematical and philosophical instrument maker in Dublin. He was born on the 2nd of February 1800. He showed an early inclination to follow his father's business, and during the delivery of a course of lectures in Trinity College, by Sir Humphrey Davy, both father and son were engaged to assist in making the necessary arrangements for the proper illustrations of the lectures. Whilst so employed, young Yeates availed himself of the opportunity thus opened to him for improving his knowledge of the theory and construction of the philosophical apparatus used in the experiments.

When Captain Drummond suggested the idea of applying the brilliant limelight, which has since been known under his name, for rendering distant stations visible, and which has been found so valuable in the operations of the Trigonometrical Survey, he applied to Mr. Samuel Yeates for his aid in the construction of an instrument for showing the limelight to the best advantage. Andrew Yeates, to whom was given most of the responsibility of the work, spared no time in making himself acquainted with all the details required by Captain Drummond. When he saw the great brilliancy of the light, and was informed that the chief object of the invention was the measurement of distant angles of stations made visible by it, though inaccessible, either from being separated by broad channels of water, or from any other cause, and that the object was the construction of an accurate topographical representation of the British Isles, he determined to make himself acquainted with the whole subject, and by perseverance and enquiry, he was able to realise the great importance of the operations of the Ordnance Survey, and of the necessity and value of having instruments of precision for that undertaking. His practical skill in this class of surveying instruments was fully acknowledged in his after life. His anxiety to enlarge his knowledge of the peculiar details of the instruments used for surveying purposes created a greater desire to become acquainted with the construction of larger astronomical instruments, especially those at the Royal Observatory at Greenwich, then consisting chiefly of Troughton's Transit and Mural Circle, Ramsden's Equatoreal, and a few other less noted instruments. He therefore came to England in 1821, and on his arrival in

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London he fortunately made the acquaintance of Troughton, with whom he worked several years. In 1833 he was employed at the Observatory, under the superintendence of the great optician, for the readjustment and repair of the instruments—a work which he performed not only to the satisfaction of his employer, but also of the Astronomer Royal, Mr. Pond. Having been for a long time desirous of becoming acquainted with the details of the Greenwich instruments, this work was peculiarly gratifying to him. From this time Mr. Yeates applied himself principally to the manufacture of mathematical and surveying instruments, in which he has introduced many and important improvements, for which he has received honourable mention on various occasions.

Naturally of a studious and retiring disposition, Mr. Yeates was little known by the general public, but he was much esteemed by a large circle of scientific acquaintances as a careful observer, and, as a manufacturer, for the excellency of his instruments. In him they could repose confidence in his ability as a mechanician, and might rely on his assistance, which he was always ready to afford. His health at last failed from a too sedulous application to business, from which he eventually retired, and spent his closing years in the enjoyment of a country life, surrounded by a select circle of valued friends. His death took place on February 16, 1876, having just completed the seventy-sixth year of his age. Mr. Yeates was elected a Fellow of our Society on March 8, 1861. He was also a Fellow of the Royal Microscopical Society, and a Member of the Society of Arts.

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Proceedings of Observatories.

The following Reports of the proceedings of Observatories during the past year have been received by the Council, excepting that of Melbourne, which has been compiled from Mr. Ellery's Report to the Board of Visitors in June last.

Royal Observatory, Greenwich.

The ordinary observations with the Transit-Circle and Altazimuth have been regularly made during the past year, their number being rather larger than usual. For the first three months the readings of the four supplementary microscopes of the Transit-Circle, as well as of the six ordinary microscopes, which had been fitted with new micrometer screws, were systematically taken with every observation, and the comparison of the two sets showed that the screws were sensibly free from periodic error. To eliminate the effect of wear in future, it is proposed to reverse one micrometer in each pair, so that the springs will act in opposite directions. It has recently been discovered that one of the pivots of the Transit-Circle had been much cut, probably by a grain of sand, which might have accidentally fallen on the Y when the instrument was raised. The roughness has been carefully burnished down by Mr. Simms, and a satisfactory determination of the pivot errors has been made after several failures caused by instability of the apparatus.

The Sidereal Standard Clock has been cleaned lately, having shown considerable irregularities of rate, and finally stopped from the effect of dirt in the train.

The Great Equatoreal has been almost entirely devoted to spectroscopic work, the results of which have, to a great extent, been given in the *Monthly Notices*. The motions of 34 stars have been determined in the past year from the displacement of lines in their spectra, the agreement with Dr. Huggins' results being very remarkable, considering the delicacy of the observation; and, as a check on the principle of the method, the displacement has been measured in the case of the Moon and *Venus*, for which the motion is known from other considerations. Determinations have also been made of the displacement due to the rotation of the Sun and of *Jupiter*. No measures have yet been obtained of the lines in the spectra of nebulæ, though a preliminary examination has been made of several of them. Observations have been made of the spectra of *Venus*, *Saturn*, and *Neptune*, as well as of some of the brighter variable stars at maximum and minimum, interesting changes having been noted in several cases. No notification of the discovery of the new star in *Cygnus*

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on November 24, reached this Observatory till December 9, when the star had become faint, and as the Equatoreal had then been dismantled, it was not found practicable to observe the spectrum till the beginning of this year. In connection with the displacement of the F line in the spectra of stars, measures of the corresponding line of Hydrogen have been made at pressures varying from 4^{mm} to 290^{mm}, which show conclusively that the line expands equally on the two sides as the pressure is increased, the position of its centre remaining unaltered. At the same time, changes have been noted in the relative brightness of the three principal lines of Hydrogen as the tension of the spark and the pressure were varied, the Hβ line alone being visible at the pressure of $0{\cdot}2^{mm}$, which was the lowest at which the spectrum was observed. This work was much delayed by the necessity for extensive repairs to the Crookes air-pump, and was further hindered by the presence, on many occasions, of a complicated spectrum (possibly due to some impurity), which overpowered the ordinary spectrum of Hydrogen. The Sun's chromosphere has been examined on every favourable opportunity, but the prominences have been generally small, and on 30 per cent. of the days of observation were altogether absent.

In consequence of stiffness in its motion, the Great Equatoreal has been examined lately, and the upper pivot has been found to have been much worn by the friction-rollers, whilst the pivots of the latter had "fired." The mischief has been remedied by Mr. Simms, who has effected a great improvement in the movement of the instrument. The only recent alteration to the Spectroscope has been the mounting of the Collimator-object-glass in gymbals, which allow of its being tilted sufficiently to correct the astigmatism of the prisms. This plan has been found to answer perfectly.

A Direct-vision Spectroscope has been recently made by Mr. Hilger on a new plan, in which advantage is taken of a property of the "Half-prism" to obtain great dispersive power with two, or at the most three, "Half-prisms." As this Spectroscope, though on a small scale, appears to be greatly superior both in dispersive power and brightness of spectrum to the large Spectroscope with its train of ten compound prisms, a larger instrument on the same plan is being made by Mr. Hilger for the Royal Observatory, and it is anticipated that, independently of its greater power, it will be found to have some advantages as regards ease of manipulation over the old form.

The past year has been very unfavourable for Solar photography, only 164 days having been sufficiently clear for this purpose, and on 64 of these there was a complete absence of spots, though faculæ were usually present. The areas of all spots and faculæ on the photographs have been measured to the end of 1876, and the determination of their position-angles and distances from the centre of the Sun's disk has been commenced with Position-micrometer which Mr. Simms has recently made for

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the measurement of Solar photographs. With this instrument the areas will be determined at the same time as the Heliographic Co-ordinates. Some photographs of the Moon, *Jupiter*, and stars, as well as of the Solar spectrum, have also been taken.

The August meteors were successfully observed; but in November the weather was very unfavourable, and only a few meteors were noted on November 14.

The computations for the Nine-year Catalogue, containing over 2,250 stars, most of which are observed three or more times in each element, are considerably advanced, although last year's observations will have to be included in it. The precessions and star-constants are all computed in duplicate; all the observations up to the end of 1875 are entered, and about half of them reduced to the epoch 1872; all being corrected for inequality in the micrometer screws, which has been a work of some labour.

The volume for 1874 has been lying for some time past at H.M. Stationery Office, ready for distribution, but detained there until the decision of the Treasury is communicated on the question of gratuitous distribution as in past years.* The printing of the volume for 1875 is far advanced, the sections of observations with the Transit-Circle and Altazimuth being complete; and the reductions for 1876 are in a very forward state, notwithstanding the extra work on the Nine-year Catalogue. All the observations with the Transit-Circle are completely reduced to the end of the year. A detailed report on the progress of the reduction of the observations of the Transit of *Venus* is given under that head.

Radcliffe Observatory, Oxford.

The operations of this Observatory during the past year have been generally of the same character as in preceding years.

The volume of the *Radcliffe Observations for* 1873, of which an abstract of the contents was given in the last Annual Report of this Society, was published and circulated in the spring of last year. The following volume for 1874 is now ready for distribution, and will probably be in the hands of many of the Fellows of the Society before the day of the Annual Meeting. Its contents are chiefly a catalogue of 1,544 stars, 108 observations of the Sun, 50 of the Moon, 23 of *Mercury*, 23 of *Venus*, 15 of *Jupiter*, 11 of *Saturn*, 10 of *Uranus*, 6 of *Neptune*, and 5 of Coggia's Comet, S.P.; a catalogue of 24 double stars, many of which have been repeatedly observed, and 16 measures of the disk of *Jupiter*, giving $37''{\cdot}16$ for the value of the equatoreal diameter at the unit of distance, and $\frac{1}{17\cdot93}$ for the ellipticity. In addition, there are several series of observations of Coggia's Comet made with the heliometer, 10 occultations of stars by the Moon, thoroughly reduced, and 39 observations of phenomena

* See *Foot Note* on page 143.

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of *Jupiter's* satellites; and, finally, a considerable number of observations of shooting stars. The meteorological portion of the volume contains the usual quantity of matter, carefully arranged, and the same labour has been bestowed on the reduction of the observations as heretofore.

The reduction of the astronomical observations for 1875 has been essentially completed for some time, and the printing of the volume has commenced, three half-sheets of the Right Ascensions of stars having been printed.

The weather during considerable portions of the year 1876 was, as is well-known, very cloudy, and the amount of observations may therefore not be quite so great as in preceding years, though it does not fall very far short of it. The reductions for this year (1876) are in a forward state.

But probably the work which will be looked on with the greatest interest by astronomers generally is the compilation of a *Third Radcliffe Catalogue of Stars*, which has been begun during the past year, and in which considerable progress has been made. An index-catalogue has been formed of all the stars, arranged in order of their Right Ascensions, contained in the volumes commencing with 1852 and ending with 1870, which are the limits decided on for the catalogue, and it is found that the total number of distinct stars in this interval is nearly 4,400.

Of these, all the results, both for R.A. and N.P.D., have been written out in sheets prepared and printed for the purpose as far as the end of the tenth hour of Right Ascension, and this work is being rapidly carried forward by Mr. Luff, who has charge of the compilation of the catalogue.

As there is no extra assistance, the completion of the work cannot, of course, be looked for very early; but it is hoped that the ordinary staff of the Observatory will suffice to prevent any suspension of it for other purposes, and that it will go steadily, if not rapidly, on towards completion.

The reduction of the meteorological observations is, with regard to arrears, in the usual state, and it does not seem possible to advance it much, though no practical inconvenience with respect to the printing is experienced by this circumstance.

Oxford University Observatory.

This Observatory has now been in active operation for little more than a year, and the first report of its proceedings has been published and presented to the Convocation of the University. This latter body has, with great but not unusual generosity, increased the pecuniary grant for the maintenance of the establishment.

Three hundred and fifty photographs of the Moon have been taken with the De La Rue Reflector during the year, and they

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are still rapidly accumulating. The time is approaching when these autographic registers are to be utilised for the determination of the nutation, or inequality of the libration, of the Moon's axis. The attention of Professor Pritchard is now directed to the preparation of the details of the necessary mathematical processes; and Mr. De La Rue has undertaken to devise and provide a micrometer suitable for the measurements of these lunar photographs. Concurrently with these preparations the Professor proposes to set on foot a series of measurements with the large Refracting Telescope of five well marked and suitable points on the Moon's disk, so as to provide a check or a verification of the photographic measures. A few photographs have been taken of certain double stars, and of *Venus* and *Jupiter*, at present mainly to gain experience.

The satellites of *Saturn* have been observed during thirty-two nights. The results have been reduced, and, together with a former similar series, will very soon be in a condition for publication.

Two hundred double stars have been measured during the year; these observations also are in a state ready for printing. Considerable time and labour have been bestowed on the calculation of the orbits of certain binary stars, which hold out the expectation of definite results. In common with other astronomers, we have greatly deplored the want of sufficiently numerous and accordant observations. The method adopted in this Observatory for the determination of these orbits is a combination of both the graphical and the computational determination of the elements; and it is believed that considerable advantages have been thereby secured. In the course of these calculations a new and very simple mechanical method of calculating the excentric anomaly has occurred to Professor Pritchard, and thereby much tedious arithmetic has been avoided. It saves all the preliminary trials in the tentative methods for the exact calculation of the excentric anomaly.

The beautiful Sun Spectroscope devised by Mr. Grubb has been nearly ruined by a certain violent maltreatment which it met with in its transit along the railway to Dublin, whither it had been sent for a slight but necessary modification. Its return to Oxford is shortly expected, when restored at the expense of the railway authorities. The large Equatoreal continues to give us entire satisfaction.

Before closing this report it may not be altogether uninteresting to the Society to remind them that, concurrently with the prosecution of original research, one important object which presented itself to the University of Oxford in the institution of this establishment was the resuscitation of the science of astronomy among the students in this ancient seat of learning. The great increase of the numbers who now attend the Professor's lectures in the Observatory affords the prospect of the realisation of this hope. In furtherance of the same object the

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Convocation of the University have recently authorised the Vice-Chancellor to seek the advice of Mr. Charles Barry in the erection of a suitable lecture room and library for the use of students. These additions have, in fact, become an absolute necessity for the success of the institution, so far as University studies are concerned.

It has been asked more than once, and by none so anxiously as by the late illustrious Wilhelm Struve, when he was a Professor at Dorpat, whether the co-existence of instruction is detrimental or otherwise to the business and the original work required in an Astronomical Observatory. Professor Pritchard's experience is, that so long as it is kept within its due limits, the devotion of a portion of the Director's attention, during a part of the year, to the instruction of the highest and most intelligent order of students in a great University like that of Oxford is not only of great advantage to the studies of the place, but in many respects it is beneficial to the Professor himself. It provides the astronomer with fresh interests and a pleasant variety of occupation, while it necessitates increased precision and methodical arrangement in his own mind. Further than that, the eager and ingenious curiosity of fresh and cultivated intellects will not seldom set the Professor on the path of new enquiries, or stimulate him to the removal of old obscurities.

Cambridge Observatory.

In a year exceptionally unfavourable for astronomical observations, the places of 3,455 small stars have been obtained, as well as observations of the standard stars required for clock and instrumental corrections.

Since the mounting of the Transit-Circle, the inclination of the axis to the horizon has been gradually increasing, until it amounted to nearly seven seconds, the east end being the higher. Mr. Simms has lately reduced the support of the eastern pivot by scraping, so as to make the axis more nearly level. The west end is now higher by rather more than one second.

In order to improve the illumination of the wires in a dark field, Mr. Simms has given a cylindrical form to one surface of the prisms in the eye-piece. Although some improvement is thus effected, the light is not yet sufficient for satisfactory observation. This is of the less consequence, however, as it is found that by placing a coloured glass before the perforation in the axis, the light in the field can be moderated, so that stars may be observed in the ordinary way to the lowest limit required in the Zone observations.

The discrepancy in the Nadir-point of the Transit-Circle, arising from shake in the telescope tube, had been already

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reduced to a very small quantity, not exceeding about one-tenth of its original amount, by means of screws connecting the outer and inner portions of the tube. Mr. Simms has now inserted stronger screws than before, and it is hoped that, in consequence, this discrepancy will entirely disappear.

The alterations kept the Transit-Circle idle during November and December, but this is the less to be regretted, as there was hardly a night on which Zone stars could have been observed.

By means of some additional assistance in computation, supplied by the Sheepshanks Fund, satisfactory progress is being made with the reductions.

All the observations are entered in the reduction books, and the means taken.

The reductions of standard stars, both in Right Ascension and North Polar distance, are completed to the end of 1875, and the Right Ascensions for 1876 are approaching completion.

The apparent North Polar distances of the Zone stars are obtained as far as the end of 1873, and the calculation of the Right Ascension is now in progress.

The Transit Clock was taken to London in March 1876, by Mr. James Brock, of 64 George Street, and underwent a thorough examination and cleaning. Since that time its rate has been much more satisfactory than before.

A new line of railway in connection with the Great Northern system has been lately projected, which is to pass at the distance of about 550 yards from the Observatory, between it and the town of Cambridge. It is hoped that this scheme will not be carried out, as it is Professor Adams's opinion that so great a proximity of the line would be very injurious to the work of the Observatory.

Dunsink Observatory.

During the year the Meridian-Circle has been employed in continuing the observations of the Red Stars contained in Dr. Schjellerup's catalogue. Other stars have been from time to time added to the working list, chiefly taken from the extensive catalogue of Red Stars, prepared by Mr. Birmingham, and now in course of publication. The reductions of these observations are in progress, and have advanced considerably since the date of the last Report. It is intended that each of the stars referred to shall have its co-ordinates determined at least twice in each of the positions of the instrument. Several of the minor planets have been observed as opportunity offered during the year, and their places are now being compared with those of the Ephemerides of the *Berliner Jahrbuch*.

In October 1876, a series of observations of *Polaris* was

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commenced for the improvement of the adopted co-latitude, and has been continued to the present date. During each set of observations of *Polaris*, above or below the pole, the Transit-Circle is twice reversed, and the observations are equally divided between the two positions of the instrument. Half the observations are direct, and half by reflexion, distributed as symmetrically as is practicable. It is contemplated to continue this series for some time to come.

The South Equatoreal is being employed in the investigation of the parallaxes of some of the Red Stars above mentioned, together with other stars of physical interest, either on account of variable light, large proper motion, or unusual spectra. A great number of measures have been made, and their reduction is being actively proceeded with.

In addition to the new Sidereal Clock, by E. Dent & Co., mentioned in last year's Report, and used up to the present time, the Observatory now possesses an excellent Mean Time Standard Clock, by Booth, of Dublin, which is employed for the electric control of a clock at the office of the Dublin Port and Docks Board.

A Chronograph, with two barrels, for registration of observations made with the Transit-Circle and South Equatoreal, has been ordered from Mr. Grubb.

The Royal Observatory, Edinburgh.

The Budget granted by H.M. Government for the support of the Royal Observatory, Edinburgh, during the past year, for all salaries and all office expenses therein, has been under £1,100.

The work performed at the same time by the Astronomer and the two assistant astronomers thence maintained, has been:—

1. The service of daily distributing correct time by means of electric time-ball, time-gun, and controlled clocks.

2. The computation of the meteorological observations taken twice a day throughout the year at 55 stations of the Scottish Meteorological Society, for the Registrar-General in Scotland.

3. Calculations for the Edinburgh Star Catalogue; at which the Astronomer reports that the two assistant astronomers, Mr. Alexander Wallace, M.A., and Mr. Thomas Heath, B.A., have greatly distinguished themselves for steady and untiring devotion, both by day and by night, to the multitudinous figure work required.

Among the chief incidents during the period have been:—

1. In January 1876, the temporary contribution by the Astronomer of several pieces of apparatus to the Loan Collection of Scientific Instruments at South Kensington, London.

2. In February, the appointment by H. M. Office of Works in

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London, of Mr. Christie, of Greenwich, to examine the Edinburgh Equatoreal, not yet out of their contract with the maker, and to report to them upon it.

3. In June, the construction in France, at the Astronomer's private expense, of a large spectroscopic instrument, such as the Royal Observatory, Edinburgh, has long been in urgent need of, but was never able to obtain the necessary funds for, from any other quarter.

4. In July, the arrival of a Government Commission of Enquiry, under the presidency of Lord Lindsay, to report upon everything relating to the Observatory.

5. In September, the breakage, by a mad sailor from Leith, of the whole of the Observatory's deep-soil thermometers, whose regular observation, during 39 years past, has formed a distinct and not unimportant branch of the work of the Observatory. The man who committed the mischief is now in a lunatic asylum maintained at the public expense; but the Observatory has no funds wherewith to repair its dismal loss.

6. In December 1876, the furnishing by the Astronomer, at command of H.M. Principal Secretary of State for Home Affairs, the Right Hon. R. Assheton Cross, M.P., suggestions as to renewing the deep-soil thermometers; these being viewed as instruments successfully proved by previous experience here, and more recently at the Royal Observatory, Greenwich, to have a direct bearing on certain grand cycles of other than annual heat-waves affecting the Earth from without.

Glasgow Observatory.

The operations at the Glasgow Observatory during the past year have mainly consisted in reducing to the mean equinox of 1870, and preparing for the press, the meridional observations of stars, which have been accumulating at the Observatory since the year 1860. The task is a very laborious one, as is well known to those who have had experience of such observations; but in an Observatory like that of Glasgow, where the provision for assistance is on a very limited scale, it is especially so. Professor Grant has recently called the attention of the Town Council of Glasgow and the Clyde Trustees to the desirability of their co-operating with the Observatory more effectually than heretofore in supplying the City and Port of Glasgow with the advantages of correct time. The Town Council have cordially taken up the subject, and it is probable that ere long a considerable extension will be given to the system of controlling clocks by electricity, which has been in successful operation here during the last thirteen years.

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Kew Observatory.

The photoheliograph not being in use at Kew has been deposited for the past year in the Loan Collection at South Kensington, where it has been exhibited, together with a number of Solar negatives.

The re-examination of the measurements of the Kew Sun pictures, taken during the ten years 1862–1871, has been steadily carried on under Mr. De La Rue's direction, and has now advanced as far as the middle of 1870. Progress is somewhat slow at present, owing to the enormous number of spots which the pictures contain at this epoch, many of them having over forty, of which accurate determinations of position are made. A correction for the optical distortion of every picture is now being applied to the measurements.

The ephemerides for the whole period of the Kew Sun-spot observations have been re-calculated by Mr. Marth, and are now in the Observatory. Mr. Marth is now engaged on the reduction of the measurements of the Solar photograms.

At the request of Mr. Hind to Mr. De La Rue, a careful inspection has been made of the Kew Sun pictures from 1858 to 1875, with a view to obtain evidence as to the existence of the intra-Mercurial planet. The observations bearing on the question have been communicated to that gentleman. The whole of the expense attendant on the Sun work has been borne by Mr. De La Rue.

Mr. C. S. Peirce, of the United States Coast Survey, who has recently been making pendulum observations at Berlin, Geneva, and Paris, arrived at the Observatory in June; after having had the necessary fittings put up in the pendulum-room, he erected his apparatus, and made a complete series of vibrations. He has since returned to America.

The magnetical and meteorological work, to which the attention of the Observatory is chiefly directed, has been prosecuted continuously, and a large number of instruments have undergone verification in the department devoted to that duty.

Liverpool Observatory, Bidston, Birkenhead.

No important change has been made in the working of this Observatory during the past year.

About 300 new chronometers are tested annually in the three definite temperatures of 55°, 70°, and 85° of Fahrenheit.

Makers are much more successful than formerly in so adjusting the weights on the balance, that the maximum gaining rate shall be at about 70° of Fahrenheit.

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The average loss at 15° from the temperature of maximum gaining rate is still found to be between six and seven tenths of a second, and at 30° between two and three seconds a day.

About twenty years ago, a few chronometers were tested at the old Liverpool Observatory, the balance rims of which were cut through at 90° from each end of the balance arm, and four small weights were used. By means of three holes, for small screws, between each weight and the balance arm, the final adjustments for compensation were greatly facilitated. The loss at 30° from the temperature of maximum gaining rate, in chronometers with balances so made, did not appear to be more than the loss at 15° with balances made in the ordinary way. This subject is well worthy the attention of chronometer makers.

Temple Observatory, Rugby.

The measurement of the positions and distances of double stars has, as in previous years, been the chief work of this Observatory. Owing principally to the unusually bad weather, the number of stars measured, 183, is somewhat small. The selection includes many stars of which the binary character is more or less doubtful, the examination of which has been undertaken in preparation for the list of double stars recently presented to the Society by Mr. Wilson and Mr. Gledhill.

The spectroscopic observations of the Sun have been discontinued, as they are now regularly made at places which enjoy a better climate. The earlier observations have been published by the Royal Society in conjunction with Mr. Lockyer's; and those of later years will be published by the Rugby Natural History Society.

The Spectroscope on the 12-inch reflector has been arranged by Mr. Seabroke, for the examination of the spectra of stars, with the view to obtain confirmatory measures of the rates of their approach or recession, and some progress has been made in this direction.

As in previous years, considerable attention has been paid to the educational use of the Observatory, which receives many visits from members of the school.

The existing wooden Observatory being in a bad state of repair, it has been decided to build a new and permanent one, with a curator's cottage adjoining, and the Governing Body have purchased a suitable site. They are, however, unable to contribute towards the expense of building; and a fund is being accumulated for this purpose. Mr. E. Crossley has presented a transit instrument, and Mr. Wilson would most thankfully receive any gifts, whether of money, instruments, books, or

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photographs, which will advance the objects of the Observatory. The subscriptions at present amount to about £425, and the total sum required will not be less than £1,000.

Stonyhurst Observatory.

The astronomical work at this Observatory during the past year has been somewhat interfered with by the sickness of the first assistant, and by the change of the computer in the meteorological department. The uninterrupted series of meteorological and magnetic observations, and their reduction, demanded most of our time, but the phenomena of *Jupiter's* satellites, and the usual watch for meteors, were not neglected. A number of experiments were made with the spectroscope for determining the easiest method for simultaneous observation of the chromosphere and solar limb, with the view of preparing for the Transit of *Venus* in 1882, or any similar phenomenon. Previous to this year the Observatory was not provided with a chronograph, but one has lately been procured from Paris, to be used principally for small differences of R.A., in mapping small portions of the heavens, and in observations of *Mars* this year. More time than usual has been devoted lately to the instruction of students in methods of observation.

Mr. Barclay's Observatory, Leyton, Essex.

The work of the past year has mainly been the observations of double stars. Eclipses, occultations, and phenomena of *Jupiter's* satellites have also been observed when possible. It is proposed to publish a fourth volume of Observations at the close of the present year.

For the last two years the weather here has not been very favourable for astronomical work.

Mr. Bishop's Observatory, Twickenham.

Mr. Bishop's Observatory was closed at the end of last year. Purposing to reside for the greater part of the year in the South of Europe, it has been his intention for some time past to relinquish astronomical observations at Twickenham, and during the last fifteen months the Observatory has only been retained in operation with the view to endeavour to complete several of the charts of small stars lying near the ecliptic, chiefly where it

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is crossed by the *Via Lactea*, and consequently where the formation of such charts, from the great number of the stars, is necessarily very slow and tedious. The weather of the past twelve months has been generally unfavourable for such work in this locality, but two additional charts have been completed. Variable stars, principally those detected at Twickenham, have been watched on nights when the small star-work could not be advantageously proceeded with, and a list of these stars, with particulars showing the grounds upon which their variability has been inferred, is ready for the press, and will shortly be distributed, together with the original observations of comets, *i.e.* differences of R.A. and declination with comparison stars, taken at the Observatory.

Mr. Bishop has presented his 7-inch equatoreally-mounted refractor, and other instruments, with his astronomical library, to the Royal Observatory at Naples, to which they are now in course of removal.

Colonel Cooper's Observatory, Markree.

Micrometrical measures of double stars have been continued by Dr. Doberck during the past year. The usual meteorological observations in the manner described in the previous Report have also been made. The exposure of the refractor in the open air for so many years, without proper protection from wind and rain, has seriously affected the instrument, which Dr. Doberck fears can never be remedied.

Mr. Edward Crossley's Observatory, Bermerside, Halifax.

As in previous years, the observer's attention has been directed almost exclusively to the measurement of double stars. The well-known binaries have been measured as often as the exceedingly bad observing weather permitted, and a large number of Σ's stars have been examined with a view to the formation of a complete list of those deserving of careful attention for some years to come.

The weather of 1876 was very bad. The number of nights in which some work could be done was 75; of these 40 were bad and 34 fair: one only was fine enough throughout for the measurement of the most difficult objects.

Very complete lists of measures of all the most interesting double stars have been collected, and much historical matter gleaned from the scientific journals, transactions, &c., which are to be found in the Society's library.

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Mr. Huggins' Observatory.

During the last two years arrangements have been in progress for the application of photography to the spectra of the stars. For this purpose a Reflector with a speculum of 18 inches diameter has been mounted in the place of the 15-inch Refractor. The motion of the driving clock was then found to be not sufficiently uniform for these observations. Mr. Grubb, by means of an original contrivance, has successfully applied to the clock the control of a seconds pendulum in electric connection with a sidereal clock. This system works quite satisfactorily.

The spectroscopic part of the apparatus is constructed with a prism of Iceland spar and lenses of quartz. This apparatus is so arranged that a solar or electric spectrum can be taken on the same plate, for comparison with the spectrum of the star.

After an extensive trial of different photographic processes, preference has been given to dry plates. Among other advantages, a dry plate can be left in the apparatus until the following day, when a solar spectrum can be taken upon it through the half of the slit which was closed when the instrument was directed to the star.

In the early part of 1863 photographs of the spectrum of *Sirius* were taken in this Observatory, but from several causes no distinct indications of lines were obtained. Other investigations prevented these experiments from being pursued further at that time, but the intention of continuing them was never abandoned.

During the past year spectra with distinct lines of *Sirius*, *Vega*, *Venus*, and the Moon, have been obtained in juxtaposition with well-defined and detailed solar spectra. The continuously unfavourable weather for the last few months has prevented as yet the extension of this investigation to the spectra of other stars.

Lord Lindsay's Observatory, Dun Echt, Aberdeen.

The past year has been chiefly devoted to the continuation of the reduction of observations immediately connected with the Transit of *Venus*. At the same time, many of the instruments used at Mauritius have been remounted and tested.

The 15-inch Grubb refractor has been revised in several of its details, and a few observations have been taken with it. In particular may be mentioned determinations of the wave-lengths of the bright lines in the spectrum of Dr. Schmidt's *Nova*.

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The Earl of Rosse's Observatory, Birr Castle, Parsonstown.

The past year has been about an average one for astronomical work at Parsonstown.

On 41 nights 161 sets for nebulæ have been made with the 6-foot reflector, and eight observations with the 3-foot are recorded.

The satellites of *Saturn* were observed on four and that of *Neptune* on two nights.

The work with the 6-foot consists chiefly of micrometrical measures, and has been directed as far as possible to points on which, in preparing past observations for publication, further examination seemed most required.

The 3-foot is now re-mounted as an equatoreal in, it is believed, a very satisfactory manner. It remains of the Newtonian form, but it is intended to arrange for its occasional employment in the Herschelian, or front view form, and this has been all along kept in view. The instrument has been found extremely steady, and Lord Rosse's assistant, who has observed with it on windy nights, has never complained of the least vibration. The clock appears to carry it with sufficient regularity for ordinary work in Right Ascension without the assistance of the controlling pendulum, which was ready for application. The gallery and telescope can be moved with ease, and the motions of both within a considerable range are within the control of the observer. When arrangements have been made for enabling him to read the setting circles from the eye-piece, and a collimator for correcting the axis of collimation has been fitted, Lord Rosse believes that he shall possess an instrument from which, owing to its universality of range and its general handiness, much useful work may be expected, notwithstanding its inferiority to the 6-foot in "space penetrating power."

It is intended after a few small additions (including those mentioned above) have been satisfactorily carried out, to describe fully the mounting, which differs in several particulars from any hitherto constructed, and of which a model, showing the general arrangement, has been deposited in the Loan Exhibition of Scientific Instruments.

The meteorological observations continue to be made without alteration, and a monthly return is sent to the Meteorological Office. The return of rainfall for the year only is sent to Mr. Symons, and the Observatory has been just selected as one of four which are to send weekly returns of temperature to the Registrar-General for Ireland.

Colonel Tomline's Observatory, Orwell Park, Ipswich.

Observations were made at this Observatory during the spring of last year for the comparison of the light of *Venus* with that of

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the full Moon, and after several attempts a most successful result has been obtained, which has already been communicated to the Society. The equatoreal has been employed to make a series of comparisons of *Venus* with λ *Geminorum* near the time of their conjunction on August 17 last, and, although only with partial success, some facts were elicited that have been thought of sufficient interest to merit the notice of astronomers.

With the meridian instrument it has been found possible to complete the determination of the longitude of the Observatory from transits of the Moon and culminators.

A comparison of the Right Ascensions of the catalogues of Greenwich (1864) and Armagh, has shown that, of 2,028 stars whose proper motions have been investigated, 196, or nearly 10 per cent., differ by a larger amount from the present adopted proper motions than can be supposed to be due to errors in the catalogue places themselves. Each of these stars has therefore been observed upon the meridian on three separate occasions, in order to obtain the latest possible data for the further prosecution of the enquiry. The reduction of these observations, together with those for the determination of the longitude, are now being proceeded with.

Owing to the non-discovery of comets during the last two years, the main feature in the plan of operations proposed for the work of this Observatory cannot as yet be carried out. Among the questions that may enter into the plans for the ensuing year it is hoped that stellar photometry may take a prominent place.

Royal Observatory, Cape of Good Hope.

The volume containing the Meridian Observations made during the years 1871, 1872, and 1873 has been distributed for the use of astronomers. It contains positions of all the stars in Lacaille's zones, and some other stars of about the seventh magnitude, within fifteen degrees of the South Pole.

A printed copy of the volume of Results, 1874, but without the Introduction, which is not yet passed through the press, is forwarded with the present report.

The Catalogue for 1874 contains the mean places of 1,246 stars; nearly all observed three times. The stars consist chiefly of Lacaille-stars, in the zone 165° to 155° N.P.D. The discordance between the Nadir points which existed in 1871 to 1873 has sensibly disappeared, since the readjustment of the Transit-Circle by Mr. Stone. The corrected results of 1871–1873 agree, however, very closely with the corresponding observations made in 1874.

A Catalogue has been formed from the observations made here from 1834 to 1840, both inclusive. Some considerable

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progress has been made in the printing, but this has been stopped for some time, to allow of the results for 1874 being passed through the press.

The observations made during the year 1875 are reduced to mean places. The Catalogue will contain positions of more than 2,000 stars, chiefly from Lacaille's zones, 155° to 145° N.P.D. Each star has been usually observed three times.

The observations made in 1876 have consisted chiefly of Lacaille stars in the zone 145° to 135° N.P.D., but many stars of the seventh magnitude, not in Lacaille, have also been observed. The total number of stars observed is about 2,200, and, with the exception of 10 or 12 which have only been observed twice, each star has been observed three times.

The working Catalogue for 1877 contains Lacaille stars in the zone 135° to 125° N.P.D., Brisbane's stars of not less than the seventh magnitude which have not yet been observed, and a few stars of the eastern zones which it has appeared desirable to re-observe.

Arrangements have been made for the formation of a general catalogue, which is intended to include all the observations made here from 1871 to 1878. Some considerable progress has been made in the systematic preparation of the materials already collected, but much more might be done in that direction if our computing staff were slightly increased.

The Photoheliograph was mounted and brought regularly into use in February 1876. Photographs were obtained on every clear day during the months of February, March, and April, but the weather then broke up, and it has been found impossible to carry on the work with regularity without an increase of the staff, or without seriously interrupting the works in progress. This has not been considered desirable. The photographs were all taken by Mr. Stone without assistance. A considerable number of absolute determinations of the magnetic elements have been taken by Mr. Stone during the year 1876.

The Meteorological observations have been taken with regularity, and reduced.

A distribution of time over a considerable portion of the Colony has been carried out with accuracy and a regularity only limited by occasional breaks in the telegraphic communications.

The work of the year has to some extent been interrupted by the resignation of one of the assistants, and a long delay in filling up the appointment.

Melbourne Observatory.

It appears from Mr. Ellery's last Report to the Board of Visitors of the Melbourne Observatory that the general work of the preceding year has been carried on in the same manner as before, the observations with the Transit-Circle being limited as

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much as possible, so as to allow more time for the compilation of the annual catalogues, which were in considerable arrear. The subjects of observation during the year were the usual standard stars for clock-error, the stars used for the determination of azimuthal error, and a series of special stars observed by the American Transit of *Venus* party in New Zealand for finding the latitude of their station. The number of stars observed in Right Ascension was 1,211, and in polar distance 454.

The great telescope has been employed regularly for the examination of the nebulæ and clusters previously delineated by Sir John Herschel. Seventy of these have been examined, measured, and sketched; most of them are carefully drawn and described, and are ready for publication. Mr. Ellery remarks that the drawings and measurements indicate that several of the nebulæ are considerably changed, while others appear so completely altered as to be scarcely recognisable, except by their relative position to the neighbouring stars. All these changes have been carefully noted. During the year there were 150 nights more or less fit for observing with the great telescope, but of these forty were solely occupied with visitors, and quite lost for astronomical work. Perhaps, as an act of policy, this great interference in the observing duties of the staff may be necessary in a Colonial Observatory, but it seems rather too great a sacrifice to give up more than a quarter of the stated work of the observers to satisfy the curiosity of unprofessional star-gazers.

Several drawings of *Mars* and *Jupiter* have been made—of the former in June 1875, and of the latter in May 1876. Observations also of the conjunction of *Saturn's* satellites were made in 1875, from August 26 to December 29, with the view of more accurately determining their periods. Ten only out of ninety conjunctions could be observed, owing to so much cloudy weather. These observations were intended to be continued in the autumn of 1876.

The photoheliograph has been employed, and a Sun picture has been obtained on almost every day that the sky was sufficiently clear. During the year 143 heliograms have been secured.

In the regular work of the Observatory for the ensuing year Mr. Ellery intends to continue the observations with the Transit-Circle, as the fundamental work of the establishment. The revision of Sir John Herschel's figured nebulæ is to be continued with the great telescope, and the same instrument will also be employed upon occasional planetary observations. In connection with this telescope, Mr. Ellery remarks:—"I may mention that, although the mirrors retain their high reflecting polish exceedingly well, the fact must not be overlooked that the time when they will have to be repolished will inevitably arrive, and that perhaps earlier than we now anticipate. I intend, therefore, to devote some time this year to practice in grinding and polishing large surfaces, in order that both Mr. Turner and myself may obtain further experience in the matter. I also hope to personally undertake a series of observations with the south equatoreal (8-inch), more

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especially of the objects to be observed with the great telescope, for the purpose of micrometric measurements, which will, I anticipate, enable the larger instrument to be devoted more exclusively to the figuring and revision of the features of the nebulæ."

During his recent visit to Europe, Mr. Ellery made enquiries concerning the best means of reproducing for publication the valuable collection of drawings of nebulæ now in hand; but though he inspected many proposed methods, the result was not satisfactory. He has since seen, however, some specimens of a toned lithograph, white on black ground, the work of an officer attached to the Mining Department, on which the nebulæ are represented as they appear in the telescope more nearly than by any other method which he has examined. There is, therefore, some hope that the results of the observations of the Great Melbourne Telescope will, at no distant date, be in the hands of astronomers, as there is already a considerable amount of work of great interest ready for publication as soon as the method to be employed in the reproduction of the nebulæ is decided on.

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Notes on some Points connected with the Progress of Astronomy during the Past Year.

The Numerical Lunar Theory.

The Numerical Lunar Theory, on the state of which the Astronomer-Royal has occasionally given some Reports to the Society, has advanced steadily, interrupted only by some errors in operations incurred by an assistant's trusting too much to his own judgment and accuracy. With the view of placing the work which is done in a position of safety against ordinary contingencies, a considerable portion has been already printed, in readiness for ultimate distribution, both as an Appendix to the *Greenwich Observations* and as an independent treatise. The following is the general state of calculations and of printing:—

The general form of the theory is drawn up, nearly in the same shape in which it was first exhibited to the Society (omitting for the present the terms depending on the Earth's oblateness and the change of the plane of the ecliptic), and is printed.

The first step in the application of the theory is, to develop for the left side of each of the three theoretical equations (that is, the side which depends entirely on the actual place of the Moon, but without explicit reference to perturbing forces) all the successive steps leading up to that left side as derived from Delaunay's numerical values of the three co-ordinates; which values are supposed to be not true, but so near to the truth that the squares of the corrections which they require may be neglected. This development is exhibited in numerical tables of great extent. There are 39 columns, each exhibiting a separate development as one of the steps towards the completed development of the left sides; the terms of each column consist of multiples of sines or cosines with different factors and different arguments; and the number of these terms in each column varies from 100 to 287, all carried to the 7th decimal. The whole of these results are printed.

The next step is—supposing each of Delaunay's terms to require a correction, which, before its magnitude is ascertained, must be used in the shape of a Symbolical Variation (S.V.)—to find the factors of these S.V. of Delaunay's terms, by application of which the S.V. of the terms of the left side of the equations will be formed. The theory of this transformation is printed; all preparations for the transformation are prepared, and nearly all the work is done.

It has been found desirable to abandon the use of the "Equation of Virtual Velocities," adopted in the first sketch of

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the theory, and to substitute for it the "Equation of Radial Forces." The addition which this change introduces into the calculations is small.

It will be seen, therefore, that the left sides of the equations are very nearly completed. The Astronomer-Royal contemplates the possible extension of some terms on which the more accurate movements of the apse and node depend; and, indeed, the work has been begun; but it is not absolutely necessary for the principle of the general theory, and the extension is for the present suspended.

Of the right side of the equations, which contains the computed perturbing forces, a large portion has been some time since completed, and the Astronomer-Royal contemplates a very early devotion of the powers of the establishment to the computation of the whole perturbation-side, and to the exhibition of the detailed equations which contain the solution of the whole problem.

Reduction of the Observations of the Transit of Venus, December 8, 1874.

In the Annual Report of the Council last year, page 177, the state of the Reductions was described in considerable detail. They have been continued throughout the year under Captain Tupman, assisted by Lieutenant Neate, R.N., until November, and generally four computers. The great mass of the work, prepared on skeleton forms, has been done outside the Royal Observatory. Referring to the headings of the last Report:—

(1.) All observations with transit instruments, for local time and longitude, are completely reduced.

The longitudes of Honolulu and Rodrigues by the observations of the Moon in zenith distance, are completely reduced. These two calculations required the use of three millions of figures. The zenith point of the vertical circle employed at Rodrigues was subject to variations not yet explained, and it is possible the longitude may require a slight correction.

For Kerguelen's Island, chief station, the transit work, comparisons of clocks, latitude, and instrumental constants of the Altazimuth are reduced. The observed azimuths of the Moon, about 130 in number, and each compared with a star, and the interpolations of the Lunar elements, are in hand.

An element of great importance in the reduction of these longitudes is the amount of the correction to be applied to the Moon's Tabular Place. This is the subject of a separate communication to the Society by Captain Tupman, which will be printed in a future number of the *Monthly Notices*.

(2.) The differences of longitude between the various stations

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in the Hawaiian Islands and between Honolulu and San Francisco are nearly concluded.

(3.) The *Greenwich Sidereal Times* of every photograph, micrometric measure, and other observation, in Egypt, Honolulu and Rodrigues, and of every photograph at Roorkee (Colonel Tennant's station) during the actual Transit, have been adopted, employing provisional longitudes for Honolulu and Rodrigues founded on the meridional observations of the Moon.

(4.) The whole of the calculations necessary to compare the proportions of Mr. De La Rue's material scale with its image as photographed 24 times by each of the five photoheliographs have been performed in duplicate, and the means of the results have been taken for each picture. For two of the instruments, the computation of the distortion has advanced another stage—that of arranging it in angular directions around the centre of the field. In this work, 2,800 pages of ordinary foolscap size were closely covered with figures. There remains to deduce the curve of distortion in the different azimuths, and to convert the results into a form convenient for application to the measures of the Solar photographs.

(5.) Mr. C. E. Burton continued the measurement of the photographs until the end of April 1876, when, unable any longer to support the great strain upon his eyesight, he was compelled to abandon the work. During the seven months he was engaged upon it he made upwards of 38,000 bisections with the microscopes.*

The following is a list of the photographs of the actual transit measured by him :—

Thebes (Egypt).—*Ingress.*

34 square plates with *Venus* entirely within the Sun.

28 small pictures † on a circular plate with *Venus* at internal contact.

55 small pictures on two circular plates, the planet being bisected on the Sun's limb.

Honolulu.—*Ingress.*

12 square plates with *Venus* approximately bisected on the Sun's limb.

38 square plates with *Venus* entirely within the Sun.

Rodrigues.—*Entire Transit.*

24 small pictures (*Ingress*) immediately after external contact.

23 small pictures (*Ingress*) about the time of bisection.

* We are happy to state that Mr. Burton, who is now First-Assistant at Dunsink Observatory, has entirely recovered.

† By *small pictures* are meant those containing only that portion of the Sun's limb contiguous to the planet. On *square* plates the Sun is always entire. All the measurements are along the line of centres.

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37 small pictures (*Ingress*) about the time of internal contact, *Venus* entire.

35 small pictures (*Ingress*) just after internal contact, *Venus* entire.

52 square plates during transit.

27 small pictures at *Egress* just before internal contact, *Venus* entire.

Burnham, New Zealand.

13 square plates at *Mid Transit.*

Kerguelen's Island.

Attempts were made to measure 8 square plates (at *Mid Transit*), but the photoheliograph appears to have been hopelessly out of focus on the day of the transit.

Roorkee.—*Entire Transit.*

53 small pictures at *Ingress. Venus* approximately bisected.

84 square plates during transit.

7 square plates at *Egress. Venus* approximately bisected.

Melbourne.—*Entire Transit.*

3 square plates at *Ingress. Venus* approximately bisected.

26 square plates during transit.

Sydney, N.S.W.—*Entire Transit.*

20 square plates during transit. *Venus* entire.

Eden, N.S.W.—*Entire Transit.*

16 square plates. *Venus* entire.

Woodford, N.S.W.—*Entire Transit.*

20 square plates. *Venus* entire.

Some 300 small pictures taken at Roorkee, Melbourne, and Sydney have not yet been measured; nor have any measurements yet been made for the distortion of the instruments used at these stations, Eden and Woodford.

(6.) The Tabular *local* distances of the centres of the Sun and *Venus* as affected by parallax, and the factors of corrections to distance for time and parallax, have been computed for every photograph, micrometric measure, and other observation of the actual transit in Egypt, Honolulu, Rodrigues, and for every photograph at Roorkee.

The work remaining may be briefly stated as follows:—

The completion of the longitudes of Kerguelen and Burnham, N.Z., by the Lunar observations, and of Honolulu and dependencies from San Francisco by chronometers, and of the distortion of the five photoheliographs; the determination of the distortion of the Indian and Colonial photoheliographs, including the measurement of the necessary photographs; the measurement of the remaining Sun pictures; the calculation of the local elements for Waimea and Kailua (Hawaiian Islands), Burnham, N.Z.,

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Kerguelen (3 stations), Melbourne, Sydney, Eden, and Woodford; and, lastly, the treatment of the results.

It is impossible to form an even moderately accurate estimate of the time which will be required to finish all this work. It was hoped that more would have been done during the past year, but unexpected delays occurred, one of which was a serious illness of Captain Tupman, which totally incapacitated him for work for three months; other delays are caused by the necessity which often arises of going again over work believed to be free from error.

It is not proposed to commence the printing until the calculations are further advanced.

M. Le Verrier's Planetary Researches.

In the address of Professor Adams delivered at the last Anniversary Meeting of the Society, a complete abstract is given of M. Le Verrier's planetary investigations as far as chapter xxiii., and now the Council have much pleasure in recording that at the *séance* of the Academy of Sciences held on November 20, 1876, chapters xxiv. to xxvii. of his *Recherches Astronomiques* were communicated by him, containing the detailed explanations of the theories of *Uranus* and *Neptune*, which thus complete his laborious researches on the theories of the eight principal planets. Tables of *Uranus* were presented in manuscript to the Academy at the same time. In this immense work M. Le Verrier has been able to follow the same system throughout his investigations, owing principally to the long-continued series of planetary observations made at the Royal Observatory at Greenwich from 1750 to the present day, which have been reduced with great order and precision, and made available for his purpose in such a form as cannot be found elsewhere. M. Le Verrier remarks that since the discovery of *Uranus* in 1781, a very large number of accurate observations have been made; and on account of its small magnitude the planet has been observed with the same accuracy as a star. For this reason, the observations made during the ninety-two years from 1781 to 1873 have been exclusively employed in the present investigation. In the comparison of the theory with the observations, the latter are represented with the precision that might have been expected from their small probable error.

The Tables of *Uranus* and *Neptune*, forming chapters xxviii. and xxix. of the *Recherches Astronomiques*, are both ready for the press, and the printing, it is expected, will proceed without interruption. The Council cannot refrain from offering to their distinguished Associate their sincere congratulations on the near and successful termination of his great undertaking.

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The Nautical Almanac for 1880.

In the *Nautical Almanac* for 1880, an important addition has been made to the list of standard stars, ordinarily used for the determination of instrumental and clock-errors, the apparent places of which are given for every ten days throughout the year. In observatories where observations are made at all hours of the day and night, it is highly desirable that there should be a quick succession of clock-stars, not only for the convenience of the observer in his ordinary work, but also in continuous unfavourable weather when the available time of observation is frequently confined to the few minutes' interval during temporary breaks in the clouds. This extended list will, therefore, be found very useful in observatories where the observations of stars are confined mostly to those for which apparent places are given in the *Nautical Almanac*. The new stars have been selected principally from the Greenwich clock-star list, which is annually prepared for use at the Royal Observatory, and freely circulated among the principal home, foreign, and colonial observatories. These additional apparent places of the stars given in the *Nautical Almanac* for 1880 will also be a great boon to the computer, who will in consequence be relieved of a considerable amount of daily calculation. Possibly at some future time space will be found in the Almanac to include most of the stars in the Greenwich list; meanwhile, astronomers are much indebted to the Superintendent for his very valuable and voluntary addition to our national ephemeris. As the standard stars have been well observed at Greenwich during the nine years from 1868 to 1876, it is hoped that the adopted mean places will be taken, as soon as possible, from the *Nine-year Catalogue* now in course of active preparation.

Another important feature in the *Nautical Almanac* for 1880 is the substitution of Le Verrier's Tables of *Saturn* for those of Bouvard, which have been in use since 1834. The new Tables have been communicated by M. Le Verrier to the Superintendent, in anticipation of their publication. The tabular places of *Saturn*, as well as those of the Sun, *Mercury*, *Venus*, *Mars*, and *Jupiter*, are, therefore, now derived from Tables constructed by that astronomer.

Solar Physics.

The quiescent state of the Sun during the past year has not been favourable to physical investigations, but, notwithstanding this, some interesting results have been obtained in this branch of astronomy. The Italian Spectroscopic Society* continues its

* *Memorie della Società degli Spettroscopisti Italiani.*

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work on the Solar prominences, and one of its most distinguished members, Professor Tacchini, has taken advantage of the lull in the activity of the Sun to discuss his observations of 1871 and 1873. A comparison of these two series shows that in 1873 the number of prominences had decreased to one-half of what it was in 1871, and that in both years twice as many were observed on the west limb as on the east. Further, there was in 1871 a preponderance in the northern hemisphere, whilst in 1873 the prominences were pretty equally divided between the northern and southern, with a rapid diminution in number, for both years, from the equator towards either pole. In the present year Professor Tacchini finds that the height of the chromosphere has not diminished much, and that the circulation of magnesium is as active as ever, though hydrogen prominences and metallic eruptions are now very rare. He further connects the absence of sodium in the chromosphere with the present paucity of Sun-spots, and considers it likely that this element may have a large share in their formation. The granules and faculæ appear now to be very marked, notwithstanding the absence of spots.

In partial opposition to this are Mr. Trouvelot's observations* on what he has called "veiled spots," from which he concludes—

"1. That during this year and especially during the interval from June 10 to August 18, and to a less degree to September 14, the chromosphere has been notably thinner than usual upon the entire surface of the Sun.

"2. That the granulations have been smaller and less numerous.

"3. That the light-grey coloured background seen between the granules has been more conspicuous and has occupied more space than usual.

"4. That there are spots which he has named 'veiled spots,' which are seen through the chromosphere which is spread over them like a veil.

"5. That these veiled spots are true openings of the photosphere, like those of the ordinary spots.

"6. That during this period these spots have been larger, darker, and more numerous than he has ever before seen them.

"7. That the veiled spots are scattered throughout all latitudes, though more complicated in the regions where the ordinary spots make their appearance.

"8. That he has observed spots at least within 10° of the north pole of the Sun.

"9. That the flocculent objects sometimes seen projected on the umbra and penumbra of spots are the remaining portion of the granulations composing the chromosphere, more or less dissolved by the forces emanating from the interior of the photosphere."

Professor Langley has continued his discussion of the question of the relative amount of radiation from the Solar photosphere,

* *American Journal of Science and Arts*, No. 63, xi., March 1876.

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and from the umbra and penumbra of a spot respectively, and its bearing on the *direct* effect of Sun-spots on terrestrial climates. An interesting paper by him on the subject will be found in the *Monthly Notices* for last November, and it will therefore be sufficient to mention, in this connection, that his observations show the umbral radiation to be 54 per cent. and the penumbral 81 per cent. of the radiation from the same area of photosphere; from which he concludes that the greatest admissible *direct* effect of Sun-spots is to diminish the Solar radiation by a quantity somewhat less than 1-1000th and somewhat greater than 1-1100th part, giving for the limits of possible *direct* effect on terrestrial climate three-tenths and one-twentieth of one degree centigrade.

A discussion has been made by M. Tisserand* of the observations of the Sun, taken by Carrington's method at the Toulouse Observatory in 1874 and 1875, the result being to show that either Carrington's or Spoerer's formula will satisfy the observations sufficiently well, though the motions of some of the individual spots are very erratic. M. Tisserand mentions particularly one which had such a rapidly increasing proper motion that after six days its daily motion was found to have decreased by one-tenth of its amount. Professor C. A. Young† has attacked the same question of the Sun's rotation, with the spectroscope, though rather with the object of verifying the principle of the displacement of lines in the spectrum, from the motions of the source of light, than with the idea of obtaining an accurate value of the period of rotation. From the relative displacement of the D and other lines at the east and west limbs respectively, he finds the equatoreal velocity to be 1·42 miles per second, while direct observation of Sun-spots gives 1·25. He is inclined to think that this discordance indicates a physical fact, and that the solar atmosphere really sweeps forward over the underlying surface in the same way that the equatoreal regions outstrip the other parts of the Sun's surface. This conclusion is opposed to the results of the Greenwich observations, which are in remarkably close agreement with the received value of the Sun's rotation.

Professor Young's observations were made with a fine diffraction grating by Mr. Rutherfurd, in which the spectra of the sixth and eighth orders were observed, the difficulty caused by overlapping in the spectra of the higher orders being obviated by the device of placing a prism in front of the object-glass of the viewing telescope, with its refracting edge perpendicular to the lines in the grating. The red of one spectrum is thus seen below the yellow of the next, which in turn is below the green of the succeeding spectrum, and so on. With this diffraction spectroscope Professor Young‡ has detected the duplicity of the 1474 line in the Solar spectrum, the two components being

* *Comptes Rendus*, No. 14, lxxxii., April 3, 1876.
† *American Journal of Science and Arts*, No. 71, xii., November 1876.
‡ *American Journal of Science and Arts*, No. 66, xi., June 1876.

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unequal. The coronal line corresponds to the stronger of the two, whilst the other is one of the faint lines in the spectrum of iron.

Discovery of Minor Planets.

Thirteen minor planets have been discovered since the last Annual Meeting. Though considerably less than in the preceding twelve months, yet the number is far above the general average of yearly additions to the group. The names of the planets and their discoverers, and the dates and places of their discovery, are given in the following table:—

No.	Name of Planet.	Discoverer.	Date of Discovery.	Place of Discovery.
(160)	Una	C. H. F. Peters	1876 February 21	Clinton, U.S.
(161)	Athor	J. Watson	April 18	Ann Arbor, U.S.
(162)	Laurentia	Prosper Henry	April 21	Paris.
(163)	Erigone	Perrotin	April 26	Toulouse.
(164)	Eva	Paul Henry	July 12	Paris.
(165)	Loreley	C. H. F. Peters	August 10	Clinton, U.S.
(166)	Rhodope	C. H. F. Peters	August 17	Clinton, U.S.
(167)	Urda	C. H. F. Peters	August 29	Clinton, U.S.
(168)	Sibylla	J. Watson	September 28	Ann Arbor, U.S.
(169)	Zelia	Prosper Henry	September 28	Paris.
(170)		Perrotin	1877 January 10	Toulouse.
(171)		Borrelly	January 13	Marseilles.
(172)		Borrelly	February 5	Marseilles.

The following six minor planets, the discoveries of which were recorded in the two preceding Reports, have been named during the past year:—

No. (139)	Juewa.	No. (150)	Nuwa.
„ (148)	Gallia.	„ (154)	Bertha.
„ (149)	Medusa.	„ (155)	Scylla.

It is at length found impossible to continue the computation of the opposition ephemerides usually inserted in the *Berliner Jahrbuch* for all the small planets which come into opposition during the year. Space has only been found for fifty out of 125, which will be in opposition between January 1 and December 31, 1877. Most of the planets selected are of small magnitude, and the observations must, therefore, for the most part, be confined to those made with large equatoreals, for it is found to be waste of time to look for the smallest of these planets with the present

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meridional instruments. For this reason it is to be regretted that so few of the older and larger planets are not included in the selection. In 1877, though twenty-four brighter than the tenth magnitude are in opposition, only eight of them, including the four senior planets, have a daily ephemeris; and, consequently, sixteen of the brightest cannot be observed on the meridian during this year.

From an examination of the Table of opposition-magnitudes given for this year in the *Berliner Jahrbuch* for 1879, it will be seen that by taking the means of groups of twenty-five consecutive planets ranged in the Table in the order of their discovery, the lowest limit of magnitude has been, on the average, reached. In the Table, 125 opposition magnitudes are given. Forming these into five groups, the mean magnitudes are respectively 9·6, 11·0, 11·4, 11·4, and 11·3, and by subdividing the first group into two groups of ten and fifteen, the respective mean magnitudes are 8·7 and 10·1. It has also been found that when the same planets are ranged in the order of their mean distances from the Sun, the corresponding means bear a similar relation to each other.

Discovery of a New Comet.

After an unusually long interval since the detection of a new comet, M. Borrelly discovered one at Marseilles, early in the morning of February 9, 1877, in the constellation *Ophiuchus*. Its observed position at $3^h\ 41^m$ A.M., mean time at Marseilles, was R.A. $17^h\ 13^m$, and N.P.D. 91° 17′. Its motion was rapid, increasing daily 44^m in R.A., and 3° 7′ towards the north. It had a bright and round nucleus about 3″·5 in diameter.* The last discovered comet of unknown period was detected by M. Borrelly, on December 6, 1874.

D'Arrest's Periodical Comet.

In the *Comptes Rendus* (No. 9, Août 28, 1876), M. Leveau has given the final osculating elements of this interesting periodical comet, resulting from the investigation of which a brief abstract is given in the last Annual Report. This comet was discovered by M. D'Arrest, at Leipzig, on June 27, 1851, and will be in perihelion in May next. M. Leveau's investigation is based on the observations made at the former apparitions in 1851, 1857, and 1870, and he has previously published elements for the

* The announcement of the discovery of this comet was received by telegram from M. Stephan on the day of the Annual Meeting, in time to be inserted in this Report. The comet was independently observed by M. C. F. Pechüle, at Copenhagen, on the following morning.—E. D.

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epoch 1869, October 13. By applying the perturbations produced by *Jupiter*, *Saturn*, and *Mars*, from this epoch to 1877, January 14, he has deduced the following corrected elements, from which a working ephemeris has been calculated for the convenience of observers at the approaching apparition. The new osculating elements are:—

Epoch 1877, January 14·0, M.T. Paris.

		°	′	″	
ϵ	=	301	56	54·42	Mean Equinox and Ecliptic, 1880·0.
ω	=	319	9	14·70	
θ	=	146	9	27·63	
ϕ	=	15	43	9·22	
η	=	38	53	18·04	
n	=	540″·41003			

Perihelion passage, 1877, May 10·339, M.T. Paris.

The details of M. Leveau's investigations will be published in the *Annales de l'Observatoire de Paris*.

Santiago de Chile Observations.

The observations made with the Meridian-Circle of the National Observatory at Santiago de Chile from 1856 to 1860, have lately been published under the superintendence of the former Director, Dr. C. W. Moesta, who had undertaken this duty since his return to Europe. They are contained in Vol. II. of the Santiago *Astronomical Observations*, and are given in the form of a catalogue consisting of 3,309 stars, mostly south of the equator. The reduction of the observations from apparent to mean place is given in detail for each star, and the mean Right Ascensions and north polar distances for 1860·0 for each separate observation. The results are, therefore, not so available for general use in this shape as they would have been if they were collected, the means taken, and then formed into an ordinary catalogue of stars. But from the orderly manner with which the separate results are arranged, there is not much difficulty in forming, if required, a mean result for the epoch 1860, January 1.

The volume also contains observations of the Moon and Moon-culminating stars from January 15, 1856, to December 30, 1857, and also some observations of *Mars*, *Jupiter*, *Saturn*, *Uranus*, and *Neptune*, and of a few of the minor planets, made principally in 1856. The volume, which was printed at Dresden, concludes with a comparison of the Santiago Catalogue with those of Washington, Johnson, and Taylor.

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Physical Observations of Saturn.

Mr. Trouvelot* has during the last four years had many opportunities of examining the planet *Saturn*, using the 15-inch refractor of Harvard College, the great Washington refractor, of 26 inches aperture, and the 6-inch refractor of his own Observatory, and from the observations thus made he has drawn the following conclusions, A and B denoting the outer and inner divisions of the outer ring, and C the outer portion of the interior bright ring:—

"1. That the inner margin of the ring B limiting the outer border of the principal division, has shown on the ansæ some singular dark angular forms; which may be attributed to an irregular and jagged conformation of the inner border of the ring B, either permanent or temporary.

"2. That the surface of the rings A, B, C has shown a mottled or cloudy appearance on the ansæ during the last four years.

"3. That the thickness of the system of rings is increasing from the inner margin of the dusky ring to the outer border of the ring C, as proved by the form of the shadow of the planet thrown upon the rings.

"4. That the cloud-forms seen near the outer border of the ring C, attain different heights and change their relative position, either by the rotation of the rings upon an axis, or by some local cause; as indicated by the rapid changes in the indentation of the shadow of the planet.

"5. That the inner portion of the dusky ring disappears in the light of the planet at that part which is projected upon its disk.

"6. That the planet is less luminous near its limb than in the more central parts, the light diminishing gradually in approaching the border.

"7. That the dusky ring is not transparent throughout, contrary to all the observations made hitherto; and that it grows more dense as it recedes from the planet; so that, at about the middle of its width, the limb of the planet ceases entirely to be seen through it.

"8. And, finally, that the matter composing the dusky ring is agglomerated here and there into small masses, which almost totally prevent the light of the planet from reaching the eye of the observer."

Astronomers are much indebted to Mr. Marth for the continuation of his ephemerides of the satellites of *Saturn*. No observations have, however, been communicated to the Society during the year.

* *American Journal of Science and Arts*, No. 66, xi., June 1876.

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Observations of Jupiter's Satellites at Adelaide.

Mr. Todd has employed his new 8-inch equatoreal, by Cooke, mounted in December 1874, in making a very valuable series of observations of the phenomena of *Jupiter's* satellites during the last opposition of the planet, extending from June 13 to October 15, 1876. He has recently forwarded to the Astronomer-Royal, for communication to the Society, a detailed statement of these observations, which consist of eclipses, occultations, and transits of the satellites, and also of the ingress and egress of the shadows. The local mean times of observation are given, as well as the corresponding Greenwich mean times, which are compared with the calculated times in the *Nautical Almanac*. Some notes on the physical appearance of the planet accompany the observations. A very interesting phenomenon observed more than once, independently, by Mr. Todd and by his assistant, Mr. Ringwood, occurred when a satellite was on the point of occultation. Instead of disappearing gradually behind the planet, it was apparently projected on the disk, as if viewed *through* the edge of the planet, supposing the latter were surrounded by a transparent atmosphere laden with clouds. This curious phenomenon was noticed on two occasions at the disappearance of the first satellite, when it was thus distinctly visible on, or through the edge of, the disk, for about two minutes before it was finally occulted.

Mr. Todd bears witness to the constantly varying aspect of the surface of *Jupiter*. He was much impressed with some sudden and extensive changes in the cloud-belts, as though a violent storm was raging, changing their appearance within an hour or two, or even less, not only in their form, but also in their magnitude.

Drawings of Jupiter.

Considerable attention has been directed during the last few years to the apparent changes on the surface of *Jupiter*, and a large number of careful drawings have been made from time to time. Some of these have appeared in the *Monthly Notices*, including the two interesting series communicated by the Earl of Rosse and Mr. Knobel. Following a suggestion of Dr. Lohse, of Berlin, the Council appointed a Committee for the examination of all drawings forwarded to the Society. In reply to a circular issued by the Committee, drawings from widely separated places have been received, and these have been or will be sent to Dr. Lohse, a member of the Committee, who has undertaken the collation of them. Forty-two delineations of the planet have been received from Mr. Hirst, of Sydney, and also a series of 153

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drawings from Mr. Trouvelot, of Washington. Others have been forwarded by Professor Tacchini, of Palermo, Mr. Todd, of Adelaide, and M. Lehardelay, of Fontenay-le-Marmion. These drawings all show that very rapid changes are still going on upon the surface of *Jupiter*, though the character of the equatoreal markings differ slightly from those shown upon the drawings of the planet made two or three years ago.

The Supposed Discovery of the Object perturbing the Motion of Procyon.

In former reports allusion is made to the observations of an object supposed by M. Struve to be a companion to *Procyon*, and which seemed, from a comparison of his observations with the theory previously deduced by Dr. Auwers, to be the object causing the observed irregularities in the proper motion of this star. The image of this supposed satellite is now found by M. Struve to have been produced by an optical illusion on his part, and also by his assistant, Herr Lindemann.

As long ago as the year 1844, Bessel remarked that the proper motions of *Sirius* and *Procyon* were subject to irregularities, which he conjectured must be due to the attraction of bodies in their vicinity, either not perceptible to us, or which, at any rate, had not yet been discovered. It is not necessary to allude further to the case of *Sirius* at the present time; but as regards *Procyon* the matter was put into a definite shape by Dr. Auwers, who in the year 1861 made a careful investigation of all the available observations, and showed that it was possible to reconcile the whole by the hypothesis that the motion of the star was disturbed by the attraction of an unseen object, about $1''{\cdot}2$ distant, round which it moved in a plane perpendicular to the line of sight, and in a nearly circular orbit, in a period of about forty years. For some time before this M. Otto Struve had been examining the star with the Pulkowa refractor, continuing his scrutiny without result till the 19th of March 1873, when he detected a very faint point of light following the star at a very small distance, nearly in the same parallel. As the point of light was also seen by his assistant, Herr Lindemann, M. Struve was confirmed in his belief of the objective nature of the phenomenon. He was, however, desirous that the suspected object should be looked for at other observatories possessed of sufficient instrumental power. He communicated his wish immediately to Mr. Newall, requesting him to turn his Cooke's 25-inch refractor upon it, but unfortunately Mr. Newall was absent at the time, and daylight soon afterwards prevented further investigation till the next spring. Meanwhile Dr. Auwers repeated his theoretical investigation, and calculated what change the apparent position of

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the object ought to undergo in that time, supposing it to be really the disturbing cause of the proper motion of *Procyon*. The months of February and March 1874 were singularly unfavourable for astronomical observations owing to bad weather, but on the 9th of April and subsequent days the point of light was again seen, the observed position-angle corresponding with what Dr. Auwers had theoretically found that it should be.

Before these observations of M. Struve the star had been examined with the 26-inch refractor at the Washington Observatory, but without detecting a companion; however, on the 12th of November 1874, Mr. Alvan Clark thought he saw a small object in a different position from that seen by M. Struve, and on November 25 and 26 of the same year Professor Holden saw another object within 10″ of *Procyon*, and also at a different position-angle from that seen at Pulkowa. On January 12, 1876, he and Professor Watson both saw this, and also two other faint points of light, all less than 10″ from the star, and at different position-angles, both with respect to each other, and also to that announced by M. Struve. Professor Holden suspected a still fainter companion between one of these and *Procyon*. These additional observations induced M. Struve to re-examine the subject with great care, the result of which has been to convince him that the phenomenon he had seen had no objective existence, but was the effect of an optical illusion which causes him (and Herr Lindemann also) to see under certain circumstances a faint image, or point of light, at about 10″ distance from a bright star, and nearly in a horizontal line with it. On the 17th and 18th of April 1876, he found this to be the case with the bright stars *Regulus* and *Capella*. On the 11th of the following month, both he and Herr Lindemann observed a similar point of light near *Arcturus*, which, however, they were unable to perceive again on the following night.

M. Struve intends to make some further experiments on the subject, as a warning against a species of optical illusion which has not hitherto received much attention. It is a very singular circumstance that the different position of *Procyon* in the telescope with respect to a vertical circle seems to have produced that apparent change of position-angle in the supposed satellite which, from its agreement with the theoretical investigation of Dr. Auwers, led M. Struve so strongly to believe that he had detected the body whose attraction was producing the observed variability in the proper motion of *Procyon*.

It is certainly more pleasing to record the confirmation of a supposed discovery than its withdrawal; yet the latter has occasionally to be done, as in the case of the unconfirmed satellites of *Uranus*, generally believed to have been seen by Sir W. Herschel, until disproved by modern observations. The present instance is interesting as showing the close scrutiny to which any astronomical observation is now subjected by the aid of other instruments of equal or greater power, and the consequent improbability of anything not really objective being long supposed to be so.

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Photographs of Spectra of Stars.

In an oral communication to the Society at the December meeting, giving the substance of a paper presented to the Royal Society, our President, Dr. Huggins, gave an account of the important results he had obtained in the application of photography to the spectra of stars, a work which he first took up in conjunction with Dr. Miller in the year 1863. Dr. Huggins has obtained successful photographs of the spectra of *Sirius*, *Vega*, *Venus*, and the Moon, with comparison spectra of the Sun, taken the next morning on the same plate. The spectrum of *Vega* in particular shows seven strong lines in the ultra-violet extending from G to M of the Solar spectrum, and these are so well defined as to allow of accurate micrometric measurement. Dr. Draper has also for some time past been engaged on the same work, and has obtained photographs of *Vega* and *Altair*, showing bands or broad lines in the violet and ultra-violet regions, unlike anything in the Solar spectrum. He has also taken photographs of the spectrum of *Venus*, which show a weakening towards H and above that line of the same character as that which he has photographically observed to take place in the spectrum of the Sun near sunset.

New Double Stars.

A catalogue of fifty new double stars, discovered with the 11-inch refractor of the Cincinnati Observatory, has been circulated by Mr. Ormond Stone, the Director. It has been prepared by Mr. H. A. Howe, who has arranged the matter in a tabular and convenient form for reference, exhibiting the approximate R.A. and N.P.D. for 1880, with the precessions in both elements; the estimated position-angles, distances, and magnitudes of the components; and the date of the discovery of the duplicity of the star. The stars are included between 8° and 40° south declination, and the angular distances vary from less than one second to eight seconds of arc. The greater number of the stars are of small magnitude, averaging 8 and 10 for the two objects. A few of the principal components are of the sixth magnitude, while the smallest are registered as of the eleventh.

Mr. Burnham has continued his examination of the heavens with the view of detecting close double stars not before identified. How he has succeeded in this interesting field of research can be gathered from the catalogues of new objects the duplicity of which has been first noticed by him. These have appeared in various publications—first, in our own *Monthly Notices*, and subsequently in the *Astronomische Nachrichten* and the *American Journal of Science and Arts*. It would have been more

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convenient to those who are in the habit of referring to previous results of double-star observations if a continuous series of catalogues, such as those of Mr. Burnham, had appeared from time to time in the same publication; and as the commencing catalogues of his series of measures are inserted in the *Monthly Notices*, some regret has been expressed that all of them had not been communicated to the Society.

From the large number of hitherto unknown double stars discovered by Mr. Burnham and other recent observers, it may be concluded that as their attention is now directed to the smaller classes of stars, it will be found that, like the minor planets, an almost inexhaustible field of discovery is open to any one having a good eye and a sufficiently powerful instrument. It is, however, important in the case of suspected binaries, that the angular positions and distances should be instrumentally measured, if possible, as mere estimated data should not be considered sufficiently accurate as the basis for any future determination of their orbits.

Micrometric Measures of Double Stars.

M. Dunér has recently published an important series of observations of double stars made at the Lund Observatory in the years 1867 to 1875, in the course of which nearly 2,700 observations have been obtained of some 600 stars selected chiefly from W. Struve's catalogue. The measures were made with a filar micrometer applied to a Fraunhofer equatoreal of 245 millimetres (about $9\frac{1}{2}$ inches) aperture, and 4·31 metres (about 14 feet) in focal length, and the periodic errors of the screw were carefully determined in 1876 at the end of the series of observations. Besides his own measures of distance and position-angle, M. Dunér has collated, under the head of Notes, at the end of the volume, the principal results obtained by previous observers, and has exhibited, in a tabular form, the changes which appear to have taken place, as shown by discordances from the mean. In a final table, a classification of the stars, according to the amount of relative motion of the components, is given, the largest class being that containing double stars which have not as yet changed their relative position. M. Dunér is still continuing his work on double stars, to which he hopes to be able to devote a much larger portion of his time than has been possible in the period to which these observations refer.

The following table, according to M. Dunér, shows the distribution of stars, with reference to their relative motion, since the date of the first observations:—

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Class.	Motion. °	Number of Stars.
I.	360	8
II.	180	8
III.	90	8
IV.	30	16
V.	10	46
VI.	Certain	55
VII.	Probable	51
VIII.	Insensible as yet	207
IX.	Nil, no physical connexion	11

A memoir by Mr. Knott, containing nearly 2,000 observations of about eighty selected double stars, has been lately communicated to the Society, and will be published in the *Memoirs*. In this careful work Mr. Knott has followed the excellent model of the *Celestial Cycle*, accompanying his results by descriptive and critical notes, in which (as also in M. Dunér's volume) particular attention is paid to the colour and magnitude of the components.

Doberck's New Elements of the Orbit of ω Leonis.

In a paper read before the Royal Irish Academy in April last, Dr. Doberck has given the result of his recent investigation of the orbit of *ω Leonis*, in which he has discussed with great completeness all the data at his disposal up to 1876. This star, one of the most remarkable of the double stars discovered by Sir W. Herschel, has occupied the attention of most of our double-star observers since its discovery, but its excessive closeness has made it a very difficult object to measure. For this reason, very great discrepancies are found in the observations, especially when they have been attempted with small telescopes. Notwithstanding these difficulties, the star has been carefully watched during the last fifty years, or from the time when W. Struve commenced his observations at Dorpat. The notes of the appearance of the two stars recorded by the different observers are very conflicting, for while Sir James South, in 1826, states that the components are of the sixth and ninth magnitudes, the small star being pale blue, W. Struve, about the same time, remarks that they differ but little in magnitude and are both yellow, the smaller being certainly of the deeper colour. On the other hand, M. Dembowski has more recently made them white. The change in the relative distances between the stars was noticed by Sir W. Herschel, who made notes in 1782 and 1783, that the distance between them was increasing;

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in 1795, that they were half a diameter of the smaller star asunder; and in 1804, that the space between them was nearly a diameter of the smaller one. It was seen oblong by W. Struve, in 1836 and 1838, and single by Mädler in 1843. Winnecke, in 1858, and Engelmann, in 1865, were unable to separate the two objects.

Elements of the orbit have been calculated on several occasions, but no one has paid greater attention to this star than Professor Klinkerfues, of Göttingen. But the great difficulty experienced in obtaining accurate measures has created corresponding difficulties in the calculation of the orbit. A first investigation of Klinkerfues appeared in 1855 (*Ast. Nach.* No. 990); these were followed in 1858 by a second and revised system of elements (*Ast. Nach.* No. 1,127), both of which were intended to illustrate his method of determining the orbit of a binary star; and, lastly, in his *Theoretische Astronomie*, he has published a third series of elements determined on twelve annual means of measures made to 1867, by Herschel, W. Struve, Mädler, Secchi, and Engelmann. In determining these last elements, Professor Klinkerfues considered that he had used all the available measures, but Dr. Doberck points out that many additional measures had been made at the time, though many of them have only recently been published.

That the elements calculated by Professor Klinkerfues were imperfect, and required considerable modification to satisfy the observations, was very evident to those interested in the subject, as may be seen from the following remarks of M. Otto Struve: "The elements of the orbit of *ω Leonis*, calculated by M. Klinkerfues, in 1858, are still very defective. For 1870 his ephemeris indicates the distance as 1″·06, and the direction as 10°·9, while our measures give respectively 0″·58 and 52°. Probably the erroneous result of his calculations should be attributed chiefly to the uncertainty of M. Mädler's measures, which were employed to form the last normal place for 1853. Without doubt the period of revolution will turn out to be much shorter than that found by M. Klinkerfues."

Dr. Doberck, at the commencement of his investigation, selected the angles and distances observed by O. Struve, to form his interpolating curves, and thus construct an ellipse. He found all the points well represented, but the principal star was not included in the circumference, and he was not able to alter the curve in a justifiable manner, so as to get the star inside the ellipse. He "considered it therefore not unlikely that O. Struve's measures, though as accordant among themselves as could be expected from the large refractor, were perhaps not quite free from systematic errors, though corrections had been applied as deduced from observations of artificial double-stars." By this system of interpolating curves applied to all the observed angles and distances, and by varying them when required to satisfy the observations, Dr. Doberck has determined five different sets

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of elements, of which the following are the last and definitive values:

			° ′
Node	...	...	148 46
γ	...	...	64 5
λ	...	...	121 4
ε	...	...	0·536
P	...	...	110·82 years
T	...	...	1841·81
a	...	...	0″·890

A comparison of the observed angles of position and distances, with those deduced from the preceding elements, is given, including all the known observations from 1782 to 1876. The residual errors appear small, and good evidence is shown that the measures are represented more closely by Dr. Doberck's new elements than by any of those previously published.

Dun Echt Observatory Publications.

Double-star observers will be thankful to Lord Lindsay for the publication of the first volume of the Dun Echt Observatory publications, which contains a summary or index of all the measurements of double stars included in W. Struve's *Mensuræ Micrometricæ* and appendices. The scarcity of the original volume, which is rarely found in the libraries of amateur observers, together with its inconvenient size, has induced Lord Lindsay to commence his series of publications with this very valuable and useful abstract, in which most of the information relating to Struve's measures is given. The compilation and arrangement of the catalogue, and the reduction for bringing up the epoch to 1875, have been performed by Dr. R. Copeland.

The separate columns of the catalogue contain the R.A. and declination for 1875; the lowest and highest powers used by Struve; the mean date of observation; the mean distance and position-angle as deduced by Struve; and the magnitudes and colours of the components; the latter translated from the Latin names. These translations of the colours were carefully considered, and then strictly adhered to. A table of the precessions in declination for ten years is also appended; and a diagram is given, from which the variable part of the precession in R. A. for ten years in minutes of time can be taken. The work is printed in quarto form, and has been most liberally distributed by Lord Lindsay among astronomers and scientific institutions.

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The New Star in Cygnus.

A remarkable stellar outburst, similar to that which appeared in *Corona Borealis* in May 1866, was first noticed by Dr. Schmidt, at Athens, on the 24th of November last, at 5.41 P.M., in the constellation *Cygnus*, then near the zenith. The new star, when first observed, was of the third magnitude, and of a yellow colour, near ρ *Cygni*, where Dr. Schmidt is sure that no corresponding object existed on the evening of November 20. The sky was overcast at Athens on the three following days, and most probably the outburst appeared at its full brilliancy in the interval between November 20 and 24. At midnight on the latter day the light of the star was of greater intensity than that of η *Pegasi*, noted of the third magnitude by Argelander. Its position does not appear to be recorded in the usual catalogues of small stars; certainly not in those of Lalande, Weisse's Bessel, Bode, D'Agelet, or in the *Durchmusterung* of Argelander. From an observation made by Mr. Hind at Mr. Bishop's Observatory on December 13, its R.A. for 1876·0 is $21^h\ 36^m\ 50^s{\cdot}41$., and its N.P.D. $47°\ 43'\ 21''{\cdot}5$.

Unfortunately, Dr. Schmidt's discovery was not immediately communicated to the Astronomer-Royal or to any other English astronomer, although a telegram was sent to Dr. Littrow, at Vienna, and probably to other Continental observers. The first information of the sudden appearance of the new star was only received in England in the second week in December, from the public notices inserted in the *Bulletin International* and *Comptes Rendus*. This neglect is much to be regretted, as there were eight favourable evenings at Greenwich before December 9, when spectroscopic observations might have been successfully made, and of these at least two were near the time of the star's maximum brilliancy. Principally for this reason, but also in consequence of almost continuous unfavourable weather afterwards, very few observations of the star have been made in this country. When seen by Mr. Hind on December 13, it had receded to the sixth magnitude, and was without a trace of colour. The observers in Paris were more fortunate in obtaining information, for the star was examined on December 2, during a brief interval of clear sky, by MM. Henry, Cornu, and Cazin, and estimated of the fifth magnitude. Under more favourable circumstances, on December 4, M. Cornu made some satisfactory observations of the spectrum of the star with the eastern equatoreal of the Paris Observatory, the magnitude on that day being estimated at 4-5. The spectrum exhibited eight detached bright lines on a luminous ground, with an almost complete interruption of the light between the green and the indigo. M. Cornu saw no dark lines; if they had existed they must have been very fine, and invisible owing to the faintness of the light.

Naming the bright lines according to their intensity by the

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Greek letters α to θ, their positions in the spectrum, in relation to those of certain elements, may be readily seen from the numbers in the following table determined by M. Cornu :—

	α	δ	γ	β	ζ	η	θ	ϵ
Observed	661	588	531	517	500	483	451	435
Hydrogen	656 (C)	...	...	...	...	486 (F)	...	434
Sodium	...	589 (D)	...	...	...	...	...	...
Magnesium	...	...	...	517 (b mean)	...	...	...	...
Coronal line	...	...	532	...	...	...	...	...
Chromosphere lines.	...	587	...	...	...	...	447	...

M. Cornu remarks as an interesting fact, but one requiring confirmation, that there are several coincidences shown in the preceding table which have led him to the conclusion that the bright lines in the star-spectrum correspond exclusively with the principal lines in that of the chromosphere, and therefore that the light of the star possesses precisely the same composition as that of the Solar envelope. He says: "But the most curious result, which I give here with much reserve, but which it will be very interesting afterwards to verify, is the coincidence of the line γ, very bright in the spectrum of the star, with the green line $\lambda = 532$ (1474 of Kirchhoff's scale), observed in the spectrum of the Solar corona and in the chromosphere; the feeble band θ corresponds also with a band $\lambda = 447$ of the chromosphere; one is thus led to think that the line δ corresponds rather with the bright line of the chromosphere $\lambda = 587$ (helium), than with that of sodium, 589. If this interpretation be correct, the bright lines of the spectrum of the star comprehend exclusively the brightest and the most frequent lines of the chromosphere."

The spectrum of the star has also been examined by Padre Secchi, Dr. Vogel, and others, all of whom confirm generally the previous observations of M. Cornu. Several bright lines were seen by Dr. Vogel in the red, blue-green, and blue parts of the spectrum; bright bands were also visible in the yellow and green; but these may possibly be portions of a continuous spectrum seen bright by contrast with absorption bands, of which there were as many as eight or ten. The blue and violet were brighter than in most stars with band spectra. The bright lines C, F, and D_3 were visible; b, however, was probably not seen bright, but a bright line on the blue side was noticed, which may possibly be identical with a line which under peculiar circumstances is the brightest in the spectrum of hydrocarbon. One seen in the violet may be the third line of hydrogen. Dr. Vogel remarks that there are three other stars in *Cygnus* giving quite unique spectra.

By careful comparisons with several neighbouring stars, Dr. Schmidt noted the gradual diminution in the intensity of the

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light of the star almost daily. The variations of magnitude are exhibited in the following table:—

November	24	3·0	Magnitude.	December	5	5·9	Magnitude.
,,	25	3·1	,,	,,	7	6·3	,,
,,	26	3·1	,,	,,	8	6·5	,,
,,	27	3·2	,,	,,	9	6·6	,,
,,	28	3·8	,,	,,	10	6·5	,,
,,	29	4·7	,,	,,	11	6·7	,,
,,	30	5·0	,,	,,	12	6·7	,,
December	1	5·2	,,	,,	13	6·8	,,
,,	2	5·4	,,	,,	14	6·9	,,
,,	3	5·6	,,	,,	15	7·0	,,
,,	4	5·8	,,				

At the end of the year the star was still about the seventh magnitude, and of a decidedly orange colour, with a reddish tint.

Suspected Changes in Nebula Messier, No. 17 (the Horseshoe Nebula).

Professor Holden has made a very interesting comparison of all the available drawings of the well-known nebula Messier, No. 17,* with the object of ascertaining whether any visible changes could be detected in the relative positions of the nebula and neighbouring stars. The drawings are those of Sir John Herschel made in 1833 and 1837 with his 20-foot reflector of 18½ inches aperture; of Lamont (1837) with the 11-inch Munich refractor; of Mason (1839) with a 14-foot reflector of 12 inches; of Lassell (1862) with his 4-foot reflector at Malta; Trouvelot (1875) with a 6½-inch Merz refractor; and Trouvelot and Holden jointly (1875), with the 26-inch refractor of the Naval Observatory at Washington.

To examine the question as to the motion of the nebula relative to the stars, Professor Holden has divided the drawings into three groups, the *first* consisting of those made before 1840; the *second*, of Lassell's beautiful delineation, to which a great weight is given; and the *third* of the two drawings made in 1875, one at Cambridge, U.S., and the other at Washington. To prove the existence of a change, he has considered it necessary and sufficient to show that there has been an alteration in the position of some prominent feature, such as the "horseshoe," in the interval between the epoch of the first group and the second; and that this apparent change is confirmed and con-

* *American Journal of Science and Arts*, No. 65, xi., May 1876.

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tinued in the two drawings of 1875, greater weight being given to that obtained with the larger instrument. Professor Holden remarks: "It must be remembered that with two instruments of *equal light*, hardly more discrepancy in the positions of the *brighter* portions of the nebula is to be expected than in the star-positions, for these positions are determined by the stars themselves, and can be assigned with almost no error in a nebula which contains so many stars as the one under consideration. The fainter portions may vary greatly from the smaller to the larger instruments." Tables are given by Mr. Holden containing a comparison of the relative positions of the stars as laid down in the different drawings, which, on the whole, fairly agree; and in another table he has exhibited, in a convenient form, the evidence for or against a notion of the "horseshoe," with reference to its contained stars. As a final result of the comparison, he concludes that the tables show that the stars have remained in their relative positions from 1837 to 1875, and that "the drawings, whether taken as a whole or considered according to their relative importance, show that the 'horseshoe' has moved with reference to the stars, while the *Messierian* streak has not moved; and that, therefore, we have evidences of a change going on in this nebula. This may be a veritable change in the structure of the nebula itself, such as was suspected by Schroeter, confirmed by O. Struve, and again confirmed by myself in the nebula of *Orion*; or it may be the bodily shifting of the whole nebula in space, in some plane inclined to the line of sight."

Comparisons of other well-defined nebulæ, on a similar plan to that adopted by Mr. Holden, would probably give us much information respecting the proper motions of different portions of nebulæ. The difficulty of making accurate delineations of such delicate objects must, however, make us cautious in accepting any apparent changes in the position of nebulæ in relation to neighbouring stars, unless they are confirmed by drawings of more than one observer at the beginning and end of each interval of time.

As bearing on this subject, it may be mentioned that a well-executed drawing of the nebula in *Orion*, reduced from a larger delineation, has been presented to the Society by Signor Tempel, of the Arcetri Observatory, near Florence. It is a valuable addition to the other representations of the same nebula already in the possession of this Society.

Montigny's Researches on Scintillation.

The Council have already noticed in a previous report the important researches of M. Montigny on the scintillation of the stars. In a paper contained in the "*Bulletins de l'Académie Royale de*

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Belgique" (2me série, t. xlii., No. 8, Août 1876), M. Montigny has given an abstract of the results recently obtained by him from some further investigations on the same subject, especially in relation to the connection of the intensity of the scintillations with the variations in the conditions of atmospheric phenomena. This very interesting astro-meteorological question has occupied the attention of M. Montigny for several years past, the observations discussed in the present paper extending from October 1870 to August 1876. They were continued, with occasional interruptions, during this interval as often as the state of the weather permitted, and under the influence of varying conditions of the atmosphere, and of a different temperature, which in December 1870 and January 1871 and 1876 was as low as $-9°$ and $-10°$ centigrade.

The instrument employed was an astronomical telescope of 77 millimetres aperture, with a magnifying power of 85. A scintillometer, formed of a circular plate of thick glass, was mounted obliquely in the tube of the telescope, in front of the eye-piece, and having a circular motion by means of a contrivance placed outside the telescope, by which the exact number of revolutions which the plate makes in a second of time can be ascertained. By this arrangement the image of any star towards which the telescope may be directed describes a perfect circumference in the field of the instrument. When there is no scintillation, the circle forms a continuous line presenting the general tint of the star, but when it is visible, this circular curve is broken into coloured arcs, varying rapidly, among which may ordinarily be detected red, orange, yellow, green, blue, and occasionally violet, according to the character of the scintillation. By means of a micrometer-wire placed in the focus of the telescope, the number of coloured arcs contained in the curve described by the stellar image is obtained and the amount of intensity determined. About seventy stars were selected for the experiments, varying from the first to the fourth magnitudes, and they are included in the three principal types, according to Padre Secchi's classification. The stars observed on each evening were those situated in the eastern and western portions of the heavens, and owing to the continuity of the observations this method of selection had the effect of obtaining results for each star, when situated in opposite quarters of the sky, at intervals of several months.

M. Montigny gives a series of tables of comparison between the intensities of scintillation and different meteorological data, determined from observations made at the Observatory of Brussels. The tables exhibit the intensities ranged in order of the seasons, of single rainy days, of consecutive rainy days, of days of high wind and storms, etc., leaving a comparison of other data in relation to the temperature of the air, atmospheric pressure, and some other phenomena, for another paper. Important results are shown in these comparison tables; among them it may be noticed that in some seasons it was found that the intensity of

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scintillation is decidedly greater in rainy than in dry weather, and more marked in winter than in summer, about equal in spring and autumn in dry weather, but in general wet seasons the intensity is greater in spring than in autumn. On stormy nights the scintillation increases or diminishes in intensity with the rise and fall of the barometer, being greatest on the approach of a storm, and again diminishing as it passes away. Other facts have been satisfactorily brought out, but these are sufficient to show that most interesting results have been obtained by M. Montigny from his systematic series of observations.

Progress of Meteoric Astronomy during the year 1876.

The records of meteoric phenomena during the past year comprise a few falls of aërolites, the occasional appearances of several considerable fireballs, and a few observations relating to periodical star showers, and to radiant points of meteor showers occurring with less intensity on ordinary nights of the year.

Of meteorites whose fall was witnessed, and specimens of which have been preserved, the following brief list supplies the localities and dates, and some of the particular characters of the aërolitic falls :—

Date.	Local M.T.	Locality, and Remarks.
1875, Sept. 14	4^h p.m.	Supino, Circ. Frosinone, Italy (Stone-fall).
1876, April 20	3^h 40^m p.m.	Rowton, near Wellington, Salop, England (Iron-fall, 7¾ lbs.).
1876, June 28	11^h–12^h a.m.	Ställdalen, Dalecarlia, Sweden. Three or four stones fell—the largest 4½ lbs.

Aërolitic falls of less importance, or of which the occurrences are less authentically reported, have also taken place on the following dates :—

Date.	Local M.T.	Locality, and Remarks.
1876, June 25	9^h–10^h a.m.	Kansas City, Missouri, U.S.A. No meteor seen; but a small stone, weighing a few ounces, fell—too hot to be touched immediately—on the tin roof of a house, which it almost penetrated, and bounded off.*
1876, July 8	4^h a.m.	Louisville, Kentucky. A stone fell, accompanied by a report, in the streets of the town, weighing about 2 lbs.†

* *Amer. Journ. of Science*, vol. xii., p. 316; October 1876.

† *Louisville Courier Journal* (*Scientific American*, of Aug. 12. 1876, p. 98). A large meteor (*see* below, p. 211) was seen on the same date in Indiana.

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Date.	Local M.T.	Locality, and Remarks.
1876, Oct. 19	2h a.m.	Newburyport (Mass.) and Ledyard (Conn), U.S.A. A large fireball seen at the former place; and numerous meteoric stones were found at the latter place on the day following its appearance.*

Among these meteorites, the Rowton aërosiderite is particularly interesting, as it is only the seventh example of a solid iron meteorite whose descent has been witnessed, and of which a specimen has been preserved. It fell in rainy weather, unaccompanied by any visible fireball, but preceded by two startling detonations heard northward from the Wrekin over the neighbouring villages of Shropshire for many miles. It penetrated the soil of a turf-field to a depth of eighteen inches, almost vertically, but with a slight inclination (from the north-west towards south-east), and when discovered about an hour after the occurrence it was still quite warm. It was presented to the British Museum by his Grace the Duke of Cleveland, in whose property it fell; and a cast of the meteorite may be compared with similar casts of the iron meteorites of Braunau, Victoria West (S. Africa), Nidigullam (Madras), Marysville, and Charlotte (Dickson Co.), U.S.A., of which, with that of Agram, in Croatia, the actual falls have previously been witnessed. The meteorite itself is undergoing section and preparation for an analytical examination of its composition. The stone-fall at Supino, in Italy, on September 14, 1875, happened on the same day as the appearance of the large detonating fireball in England described in last year's Report (*Monthly Notices*, vol. xxxvi., p. 216), and the coincidence appears to be particularly deserving of attention, as it was stated in the *Bradford Times* (*Nature*, September 23, 1875), that the detonation which followed the meteor's appearance at that place was so loud as to be plainly heard indoors by those who had not seen the meteor, which more clearly established its aërolitic character than had been suspected in last year's Report. The coincidence of a stone-fall on the same date, if not purely accidental, raises a reasonable conjecture that it may have belonged (with the aërolitic fireball simultaneously observed) to a shower of ordinary shooting stars whose approximately known radiant point was found to agree exactly with the true course or direction of flight of the detonating meteor; for it will be remembered that a comparison of many well-accordant descriptions of its apparent path extensively observed in England enabled the true direction and the real path of the large fireball of September 14, 1875, to be determined with more than ordinary certainty and precision.

* *New York Observer*, Thursday, Nov. 9, 1876. The asserted fall of a small stone, apparently meteoric, stated in *Nature*, vol. xv., p. 305, to have been observed at Ecclesfechan, near Glasgow, on the evening of Jan. 2, 1877, may be added to the above list of supposed falls of aërolites recently recorded.

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The fireballs of large size which have been recorded during the past year may be briefly noticed here under three separate descriptions. Among the first, or detonating class, the following appear to have been the most conspicuous examples:—

Date.	Wash. M.T.	Locality, and Remarks.
1875, Dec. 27	9h–9h 20m p.m.	Kansas, Missouri, and Iowa States, U.S. A large fireball bursting into many fragments, and leaving a luminous smoke-track, visible for 15m, commenced its course over Nebraska, 120 miles west of Missouri R., and exploded, with heavy detonations, over Missouri State. Real motion due eastward, with a steep inclination towards the Earth.
1876, Jan. 5	10h 30m p.m.	Iowa and Missouri, U.S. A large and brilliant fireball, exploding with many thunder-like reports. Its true course was nearly vertically downwards from north-west towards south-east.
1876, Jan. 31	5h 30m p.m.	Louisville, Kentucky, and Tennessee, U.S. A large fireball observed by Dr. Lawrence Smith; said by some observers to have been followed by sounds of an explosion.
	Local M.T.	
1876, June 15	8h 10m p.m.	Suez to Port Saïd. A large fireball, which burst with a very loud explosion, illuminating the sky brightly at all the stations on the Maritime Canal; moving from west to east, or from south to north, vertically over the *Déversoir*, and leaving a light streak there at the point where it exploded.

A large fireball which was perhaps also detonating (*see* below, p. 211) was observed in France at about 9h p.m., on November 5, 1876. In the second class of fireballs may be included those which have been sufficiently observed in England to afford means of determining, at least approximately, the real height and position of their tracks, and the real direction or apparent radiant-point from which they took their flight. The following list comprises all the comparisons of this kind which have been obtained from the best available descriptions, and it relates in general to those fireballs which have been most generally observed in England during the past year:—

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1876, Date and Hour, G.M.T. Size and General Appearance.	Places of Observation (available for calculation).	Meteor's Real Course (distances in B. S. Miles). Beginning: Height and Locality.	End: Height and Locality.	Radiant-point, observed. α δ	Nearest known Radiant-point. α δ
July 25, $10^h\ 5^m$ p.m. Head 15′ × 30′; green or blue, with long tail of red sparks; left no streak. (London and S. of England.)	Poplar (London) and Street (Somerset); corroborated by Hersham (Surrey) and Maidenhead (Berks). An observation at Brighton describes the meteor's path as so strongly inflected at the middle as to be wholly unconformable in the first half, although agreeing well with these accounts in the last half of its flight.	62 miles over W. pt. of Guernsey (commenced as a small shooting star 90 miles over Brittany, in France, by Poplar observation of its initial point).	27 miles over Crickdale (Wilts), near Cirencester; length of path 107 miles in "5 or 6" (Street), or (?) nearly 200 miles in "about 6 secs." (Poplar observation.)	258°—24° (near *Antares*). From the Poplar and Somersetshire observations.	258°—20° July; O_3, Neumayer. 245°—30° July; Schmidt. 262°—33° July 23; ∮568 II. Ω. 250°—35° Aug.; A_3, Neumayer. 266°—42° Aug.; Schmidt. 259°—36° Aug. 5; ∮568 II. Ω.
Aug. 11, $11^h\ 22^m$ p.m. Bright as the full Moon; left a streak for 1 m., 10° long at Cardiff, curving at last like a sickle (Crediton, Devon).	Radcliffe Obs., Oxford, with Crediton and Sunderland; corroborations at Clifton, and Writtle (Essex).	73 (± 8) miles over a point 9 miles W. of Ludlow, Salop.	45 (± 5) miles over a point midway between Neath and Llandovery (Caermarthen, S. Wales).	60° + 51° (± 2°) (near λ *Persei*)	An erratic *Perseïd*. Length of path, 58 miles in "1 second" (Oxford).
Aug. 13, $9^h\ 27^m$ p.m. About as bright as *Venus*; left a streak for 5 or 6 secs.	Buntingford (Herts), Folkestone, and Radcliffe Obs., Oxford; the last for point of first appearance only.	90 miles over Walton (near E. Dereham, Norfolk).	40 (± 4) miles over Potters Bar, between London and Hertford.	39° + 66° (± 2°) (near ι *Cassiopeiæ*).	Erratic *Perseïd*. Length of path and height at commencement uncertain; about 82 m. in "2 seconds" (Buntingford).

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Aug. 15, $9^h\ 30^m$ p.m. A fine fireball; yellow to blue or green, with long train, and some white streak remaining. Brilliant over Wales and Ireland; long, slow path; no terminal explosion.	Radcliffe Obs., Oxford, and Newton St. Loe (Bristol); corroborated at Newtown (Wales). [Douglas, Isle of Man, and Cookstown, Tyrone, Ireland, for prolongation of its course.]	69 miles over a point 10 miles W. of Gresholm Isle, Saint Bride's Bay (South Wales).	34 miles over a point 15 miles W. of Arklow (Ireland). 75 miles in "9 secs." (Newtown; 20 or 30 secs., Bath.) [By Irish and Manx descriptions pursued its course to 15 miles above the centre of Ireland, near Mullingar. Path about 130 miles?]	310°−10° (±8°) (near *μ*, *ε Aquarii*).	The apparent paths much superposed, and radiant-point only linearly defined from *δ Aquarii* to ½ (*θλ*) *Antinoï*; the adopted radiant is the middle point of this line.
Sep. 24, $6^h\ 30^m$ p.m. Two maxima, the last much brighter than full ☽; streak on last part 16 min.; white, globular, no sparks. Seen at Hull, and in Paris. Illumination over the English Channel most intense.	Orwell Park Obs. (Ipswich); St. Pierre (Dunkirk Railway), Broadstairs, Deal, Great Marlow, Dymock, (Hereford), and other generally corroborating descriptions.	58 miles over a point between Ostend and Bruges (highest observed altitude; length of path 45 miles in "3 secs." Orwell Park Observatory).	16 miles over a point 15 miles N. of Ostend.	285°+35° (±5°) (near *δ Lyræ*).	No good accordance with any previously known radiant-point. Course nearly vertical, descending at an inclination of about 15° or 20° from S.S.E. towards the N.N.W.

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1876, Date and Hour, G.M.T. Size and General Appearance.	Places of Observation (available for calculation).	Meteor's Real Course (distances in B. S. Miles). Beginning: Height and Locality.	End: Height and Locality.	Radiant-point, observed. α δ	Nearest known Radiant-point.
Nov. 8, $5^h\ 4^m$ p.m. Large and bright, even in the twilight; fire-colour, with long train and string of globes at last; left no streak.	Wimbledon (Surrey) and Hay (S. Wales) for end-point and radiant-point. New Cross (London), and other corroborations in the S. of England. Long, nearly horizontal course of 240 or 300 miles (?) in "4 or 5 secs." (Wimborne, Hants; no estimates are recorded of its entire duration.) Leisurely horizontal motion "towards S. or S.W.," at every place; (towards W. at Manchester).	50 miles over Sheffield, or 55 miles over Hull and Hornsea (alt. 20° due N. from London. This early commencement, and the length of flight at last, are somewhat inconsistent with other observations).	37 miles over the Irish Channel, 60 or 70 miles W. of Milford Haven. An earlier termination of the meteor on this line of flight, over Aberystwith is indicated by a good observation of its apparent course at Manchester.	$53° + 20°$ ($\pm 5°$) (near η *Tauri*).	A *Taurid*. The whole real course is presumptive, assuming the observed altitude at Hay 20° or 25° due West to be measured and accurate. The adopted general rad.-point, however, admits of very little variation or correction.
1877, Jan. 7, $10^h\ 31^m\ 30^s$ p.m. = ♀; yellow, and red sparks in train. Long, slow, irregular course; died out; left no streak.	Birmingham, Putney Hill, and neighbourhood of London (the exact place not specified).	76 miles over Staplehurst, Kent. First expansion at 67 miles over the channels of the Thames and Blackwater River, Essex (end and beginning points as seen in London).	33 miles over the North Sea, 25 miles N. and 90 miles E. from Cromer, Norfolk (Birmingham termination).	$44° - 16°$ to $65° - 13°$ (near γ *Eridani*; not conformable to any known meteor-shower).	Length of path 104 miles (London); 185 miles (Birmingham, ? overrated; and duration "5 to 6 secs." there). Theoretical meteor speed 12·3 miles per second.

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In addition to the above accordant observations, simultaneous records of 15 or 20 bright meteors and shooting stars, chiefly between Mr. W. F. Denning's station at Bristol, and the Radcliffe Observatory, Oxford, have been obtained, of which the particulars will afford available materials for calculation. The times of appearance and general description of other considerable meteors during the past year, as far as accounts of them have been received, appear to have been as follows:—

Date.		
1876, Feb. 4	$7^h\ 35^m$ p.m.	Nucleus with globular disk several minutes in diameter; seen moving slowly westwards, in the south, at Bristol.
	Paris Time.	
1876, Mar. 19	$11^h\ 13^m$ p.m.	Fireball recorded by M. Chapelas Coulvier Gravier, at the Observatory of the Luxembourg, in Paris.
1876, April 15	$8^h\ 33^m$ p.m.	Meteor with a bright disk; seen in the western twilight at Bristol, and at Hawkhurst (Kent).
	Wash. M.T.	
1876, July 8	$8^h\ 45^m$ p.m.	Indianopolis, and Indiana State, U.S. A fireball of the largest class; half the appar. diam. of the Moon, leaving a streak of light for 40^m; no detonation heard. Traversed an arc of 30° north-westwards from *Cassiopeia*.
1876, Aug. 21	$8^h\ 10^m$ p.m.	Bolide with large elongated nucleus. Manchester; and at London and Sheerness. (Fell in the north.)
1876, Aug. 22	$8^h\ 40^m$ p.m.	At Scarborough; very bright. Fell in the E.S.E. nearly to the sea, from alt. about 60° in the S.E.
	Paris Time.	
1876, Nov. 5	$8^h\ 40^m$–9^h p.m.	Large fireball. Departments of Marne and Aube, France; a detonation is said to have been heard in the latter district at Clery. At Choisi-le-Roy the meteor's course was from *α Aurigæ* to *α Ursæ Majoris*, and along this line it left a momentary streak. The meteor's course is directed from *Taurus* and *Auriga*.
1876, Nov. 6	$5^h\ 45^m$ p.m.	A large fireball at Orsay, Paris, moving slowly at a low altitude in the E.N.E. southwards. Bright, but smaller than the Moon's disk, leaving a slight streak on its course. Very probably a "Taurid" seen with slow foreshortened course near its radiant point.

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1876, Nov. 6	Between 8^h–9^h p.m.	A large meteor seen in Kent, Herts, and Lancashire, descending almost vertically in N. and E. (Kent and Herts), and in the West (Lancashire); (?) two meteors. Divided into two parts, or disappeared with two separate explosions. Not directed from *Taurus*.
1876, Nov. 7	7^h 19^m p.m.	Fireball in *Capricornus*; Writtle (Essex). Burst with a bright flash 6° under β *Capr.* Path 10° in 3 seconds, directed from *Saturn*. Very probably a distant "Taurid."
1876, Dec. 13	4^h 45^m p.m.	A bright fireball, in daylight, when very few stars were yet visible; seen from near London, Farnborough (Hants), &c.; in the N.E. descending from west to east with a course of some length to near the E. horizon. Yellow, bluish green, and red at last, with a trail of sparks, which remained visible for a few moments. The descriptions of this fireball's course correspond very nearly with that of the daylight meteor of December 22, 1875, at 1^h 40^m p.m., described in the last volume of these *Notices*;* and it appertains not improbably to a meteor-system of the same group, with a radiant-point near β *Herculis*.

Of the real courses of the many bright meteors here described very little is accurately known, and it is much to be desired that in describing apparitions of such remarkable phenomena observers would endeavour to ascertain correctly and express clearly the apparent positions in the sky of the tracks along which these celestial intruders upon the Earth in its motion round the Sun pass across their field of view.

The periodical star showers of the past year have been either inconspicuous or much concealed by cloudy weather, and scarcely any notes of them of very remarkable importance were obtained. A meteor shower of some intensity was observed on the night of the 18th of April 1876, at Bloomington, Indiana, U.S., of which the appearance was recorded, and some particulars were gathered by Professor Kirkwood, of the State University of that town. The meteors were sufficiently numerous and bright to attract the attention of ordinary observers, and from their description the radiant point of the shower appears to have been in the neighbourhood of the constellation

* Vol. xxxvi., p. 217.—*Erratum*: line 19 from bottom of the page, *for* Brangling, *read* Braughing.

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Lyra. As the year was a leap-year the expected time of appearance of the shower would be on the 18th instead of on the 19th-20th of April as it returns in ordinary years. Another meteor shower of greater brilliancy was observed on the night of October 18, 1876; and its appearance was similarly recorded by Professor Kirkwood from the concurrent testimonies of numerous observers of the many bright meteors which were visible at Bloomington on that night. The radiant-point was in *Auriga* or between *Taurus* and *Auriga*, and it may not impossibly have been distinct from the usual maximum recurrence of the well-marked shower from *Orion* on that date. From the narrative (above quoted) of the appearance of a large meteor (perhaps aërolitic) early on the following morning in Massachusetts, it may also be added that frequent small shooting stars were still visible there at 2^h a.m. on October 19, and it is said that two or three of the shooting stars seen at Bloomington between $9^h\ 45^m$ and $11^h\ 15^m$ p.m. on the 18th were noticed to be exceedingly conspicuous by their size and brightness. Of these and other star showers, with the exception of that of August last, no observations were obtained in England. The sky was clear during the period of the August shower, but the Moon had scarcely passed its full, and was unfavourable to observations in the later hours. The maximum of the shower occurred on the night of the 10th, and it was so unimportant in intensity compared with many previous displays that one observer watching a clear sky could at the most only count about 25 or 30 *Perseïds* per hour together with 10 or 12 sporadic shooting stars, while the numbers seen on the nights of the 9th and 11th were much less than this. Even allowing for the effect of the Moon's light in extinguishing the smallest meteors of the *Perseïd* shower, the observations all indicated very clearly a distinctly marked diminution in the intensity of the August showers in 1876 as compared with its brightness in 1875, and in several of the immediately preceding years. Among the records of the shower in England are several simultaneous observations, two of them of bright *Perseïds* (on August 11 and 13) and one of an *Aquilid* or *Aquariad* on the 15th, of which only a few calculations (those above described) have yet been brought to a conclusion. The radiant point of the shower was accurate, in spite of its faintness, near η *Perseï*; but the presence of another radiant point in *Cassiopeia* was also recognised on certain nights of the shower as exhibiting simultaneously with it a very marked activity, which scarcely, however, permitted its position to be very accurately determined. Watches were maintained without success at well-equipped stations and under favourable conditions of the sky for the *Leonids* and *Andromedes* of November 1876. At Clermond Ferrand, in France, Mr. Gruey, assisted by one companion during a part of the watch, saw only five meteors on the first and even fewer falling stars on the second morning during intervals of four hours' duration, each

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after midnight a.m. of November 13 and 14, although the sky was clear. During the hour from $2^h\ 30^m$ to $3^h\ 38^m$ on the morning of November 15, when the sky was very clear, only one meteor was observed. None of these shooting stars appear to have been conformable to the radiant point in *Leo*. The observations of the same shower in 1875, including those communicated last year to the Astronomical Society by the Astronomer-Royal,* clearly indicate that the November shower has ceased to be conspicuous on the accustomed dates; but a progressive tendency of the shower to reach its maximum on the morning of the 15th instead of the 14th of November, observable in the years ending with November 15, 1872, is noticeable in all more recent observations of the *Leonids*, and may have continued to retard its date, unperceived by observers on the ordinary nights of observation, since that time. Three small *Leonids*, leaving white streaks for two or three seconds, seen near the radiant point in *Leo* by Mr. Denning, at Bristol, on the morning of November 19 (with two others on the following morning), diverging accurately from a point at R.A. 149°, Decl. +22° †, together with the absence of any such indications of the shower in France on the mornings of the 13th-15th of November last, may perhaps be accounted for by a considerable deformation of the meteor stream, and a consequent sensible change of position of its nodal points, in the portions forming the terminal or retreating phases of the shower.

No indications of the *Andromedes* were observed by Mr. Denning on later mornings of November, and a watch for them kept at other stations on the last few evenings of the month, when the sky was clear, was also without success. The shower of the "Geminids" of December 12 appears to have furnished a large proportion of shooting stars as early as December 8 and 9; but cloudy skies on the following nights prevented the time of its maximum from being ascertained. No observations on the periodic shower-date of January 1-3, 1877, have yet been received, and it is to be feared that the unfavourable conditions of the full Moon and cloudy weather have again prevented this rarely distinguishable star shower from being satisfactorily observed.

The observations of shooting stars at the Radcliffe Observatory, Oxford (included in the publications of that Observatory for the year 1874), continued to be recorded with accuracy and amplitude during the past year; and fifteen of the meteors registered are identifiable with meteors of various magnitudes which have

* *Monthly Notices*, vol. xxxvi., p. 272, March 1876.

† For easy representation of the lengths of paths, altitudes, and azimuths of meteors, etc., in degrees, it is found convenient to employ this mode of reckoning R.A. instead of the usual method of expressing it in time, and to describe declinations north or south of the Equator with a + or − sign, as a brief way of recording the apparent paths, and hence also most conveniently in charts of this description, the positions of the radiant points of shooting stars.

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been elsewhere observed, and whose real paths it will be possible to compute with some precision. The Luminous Meteor Committee of the British Association has resumed its examination of these and of other meteor tracks communicated to it by observers, with a view to presenting in the most convenient form for their constant reference a table and map of the centres or regions of divergence of shooting stars on ordinary nights of the year, at present known with the greatest certainty to exist; and a key-map and table, constructed for this purpose by Mr. Greg, were presented, with the Report of the Committee, to the British Association in September last, as the first completed stage in the progress of their undertaking. It is also intended to embody the catalogue and map with the original lists of meteor showers by individual observers from which it is constructed, in a suitable tract or pamphlet, with instructions for recording, and directions of the days most desirable for registering shooting stars, to serve observers as a useful ephemeris to guide them in their observations; and this design the Committee hopes during the coming year to be able to carry out.

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Report of the Auditors.

The following Report of the Auditors was presented to the meeting at the conclusion of the reading of the Report of the Council, in conformity with bye-law No. 65. The balance-sheet of the Auditors, however, differs in arrangement in some minor particulars from that of the Treasurer, presented to the Council and printed in their Report, but the balances in hand as stated in the two balance-sheets are precisely the same.—[E. D.]

"We, the undersigned, being the Auditors appointed, at the meeting of this Society held on the 12th of January last, to examine the accounts of the Society, in pursuance of the 65th bye-law, for the year ending 31st of December 1876, do report as follows:—

"1. The paper writing hereto annexed and marked A, and verified with our signatures, contains a true and correct statement of the receipts and expenditure of the Treasurer, on account of the Society, from the 1st of January to the 31st of December 1876, inclusive.

"The available balances in the hands of the Bankers and the Secretary of the Library Committee amounted to the sum of £270. 15*s*. 5*d*.

"2. The paper writing hereto annexed and marked B, and also verified with our signatures, contains a true statement of the funded property of the Society on the same day, as far as we are able to ascertain it.

"3. We have examined, as far as circumstances would permit, the state of the rest of the property of the Society, consisting of

"Instruments;
"Books in the Library;
"Stock of the Society's Publications.

"With regard to the instruments, we have to report that some of them, viz. Nos. 11, 21, 32, 64, 66, 68, 71, 73,* and 79 in the list contained in the Report of the Council in 1876, are missing. The remainder, including Nos. 28 and 49 in the same list, which have been found since that report, are, with few exceptions, in good order and preservation. We have not thought it necessary to enter into minute particulars on this subject, as a very careful examination of them was made previously to the last general meeting by Mr. Lecky, the principal part

* No. 73 has been removed from the list of the Society's instruments by order of the Council.—[E. D.]

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of whose report was inserted in the *Monthly Notices* of February last.

"As no catalogue of the books in the library has been formed, we are unable to say whether they are correct in point of number. We strongly advise, in the general interest of the Society, that a catalogue should be made as soon as possible.

"We have had the same difficulty in dealing with the stock of the Society's publications as was mentioned by the Auditors of last year, though not by any means to the same extent. It is, and always will be, exceedingly difficult to check the issue of individual copies of each of the *Memoirs* and *Monthly Notices*, but they are now in a very much better state than at the last audit. The perfect volumes have been carefully packed in parcels, with the number of copies contained marked on each. We have not examined the whole, but have opened some half-dozen, selected by chance, and have in every instance found the number to correspond with the label.

"Francis Barrow.
"Arthur Brewin.
"J. Kennedy Esdaile.

"*February* 8, 1877."

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A.

RECEIPTS.

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1875	548	18	9			
„ in hand of Secretary of Library Committee:						
on account of Library Expenses ...	32	3	0			
„ Turnor Fund ...	21	0	0			
„ in hand on Petty Cash Account ...	13	4	11			
				615	6	8
Dividend on £3,700 Consols	55	0	9			
„ £5,200 New 3 per Cents.	77	7	0			
„ £4,000 Consols	59	5	0			
„ £5,200 New 3 per Cents.	77	0	6			
				268	13	3
Received on account of Subscriptions:						
Arrears of Contributions	106	1	0			
237 Contributions for 1876	497	14	0			
On account of do.	2	0	0			
28 Admission Fees	60	18	0			
20 First Contributions	32	11	0			
				699	4	0
11 Composition Fees				231	0	0
Sale of Publications at Society's rooms	52	18	8			
„ at Williams & Norgate's ...	23	1	0			
				75	19	8
Balance of Horrox Memorial Fund				38	15	0
Bequest of the late T. C. Janson, Esq., to the Lee Fund				200	0	0
Due to Assistant Secretary, Dec. 31, 1876, on Petty Cash Account				2	18	8
Due on outstanding cheque				15	0	0
				£2,146	17	3

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A.

EXPENDITURE.

	£ s. d.	£ s. d.
Salaries:—		
Editor of *Monthly Notices* (five quarters) ...	75 0 0	
Assistant Secretary (five quarters)	187 10 0	
		262 10 0
Income Tax and House Duty		5 5 0
Fire Insurance		7 16 6
Printing:—		
Spottiswoode & Co.	364 8 0	
Hazell, Watson, & Viney	187 12 0	
Holdgate Bros. (printing plates)	18 5 0	
		570 5 0
Lithography, Engraving, &c.:—		
Chatham School of Photography	5 10 0	
W. H. Wesley	51 2 0	
		56 12 0
Binding and Stitching: J. Rumfitt		39 17 3
Library expenses, binding books, &c.		138 14 6
Turnor Fund: Books purchased during year ...		48 16 3
Miscellaneous:—		
House expenses	28 7 7	
Wages	23 17 0	
Stamps and postage	49 10 8	
Carriage of books and parcels	8 8 2	
Stationery and office expenses	8 6 0	
Expenses of meetings	17 15 6	
Coals and gas	74 19 9	
Mrs. Jackson-Gwilt's annuity	8 19 0	
Fittings in Library &c.: Whitechurch Bros.	5 14 6	
Sundries	20 19 8	
Bankers' commission &c.	0 0 6	
New Cheque-book	0 8 4	
		247 6 8
Investments:—		
Purchase of £300 Consols, at 96⅜, including Commission	289 10 0	
Purchase of £200 Consols, at 95⅝, including Commission	191 10 0	
		481 0 0
Balance at Bankers', Dec. 31, 1876	253 1 10	
In hand of Secretary of Library Committee:		
On account of Library expenses	13 8 6	
„ Turnor Fund	22 3 9	
		288 14 1
		£2,146 17 3

FRANCIS BARROW.
ARTHUR BREWIN.
J. KENNEDY ESDAILE.

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B.

Assets and present Property of the Society, January 1, 1877:—

	£	s.	d.	£	s.	d.
Balance at Bankers', Dec. 31, 1876	253	1	10			
Less amount of outstanding cheque	15	0	0			
				238	1	10
Due on account of subscriptions:—						
2 contributions of 5 years' standing	21	0	0			
2 „ 4 „	16	16	0			
11 „ 3 „	69	6	0			
22 „ 2 „	92	8	0			
69 „ 1 „	144	18	0			
2 admission fees	4	4	0			
2 first contributions	2	2	0			
and one amount of	5	5	0			
				355	19	0
Balance in hand:—						
In hand of Secretary of Library Committee:						
On account of Library expenses ...	13	8	6			
On account of Turnor Fund	22	3	9			
	35	12	3			
Less amount due to Assistant Secretary on Petty Cash Account, Dec. 31, 1876	2	18	8			
				32	13	7

£5,200 New 3 per Cents., including Mrs. Jackson-Gwilt's Gift (£300).

£6,200 Consols, including the Lee Fund (£300); the Turnor Fund (£450); the Horrox Memorial Fund (£100); and Mr. Carrington's bequest of £2,000 Stock which has been transferred to the Society during the past year.

Unsold Publications of the Society, various astronomical instruments, books, prints, &c.

Two Gold Medals in stock.

Balance of Turnor Fund included in Treasurer's Account, £129. 5*s*. 6*d*.

Francis Barrow.
Arthur Brewin.
J. Kennedy Esdaile.

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Papers read before the Society from February 1876 to February 1877.

1876.

Mar. 10. The Stereo-Micrometer. Prof. Zenger.

Occultation of the *Pleiades* observed at Madras on Jan. 7, 1876. Mr. N. R. Pogson.

Abstract of Prof. Christian Mayer's paper on the Observations of Binary Stars discovered at the Mannheim Observatory, Mr. S. M. Drach.

On the proper Motions of the two components of the Binary system *a Centauri*. Mr. E. J. Stone.

On a supposed Variability of the Proper Motion of B.A.C. 793. Mr. E. J. Stone.

Micrometer-measures of *Saturn's* satellites made at the Royal Observatory, Greenwich, in the year 1875. The Astronomer-Royal.

Comparisons of recent and former Observations of B.A.C. 793, and remarks on the alleged Variability of its proper Motion. Mr. Dunkin.

Note on a Starlit Transit Eye-piece. Dr. Royston Pigott.

Observations of the November Meteors made at the Royal Observatory, Greenwich, in 1875. The Astronomer-Royal.

Preliminary Note on Photographing the least refracted portion of the Solar Spectrum. Capt. W. de W. Abney.

Reference Catalogue of Astronomical papers and Researches. Mr. Knobel.

12. On the most probable Result which can be derived from a number of direct Determinations with assigned Weights. Mr. E. J. Stone.

A list of Stars beyond the ordinary limits of Distance, inserted as double in Sir John Herschel's General Catalogue of Double Stars. M. Flammarion.

Radiant Points of Shooting Stars. Mr. W. F. Denning.

Near approach of 47 *Geminorum*. Rev. S. J. Johnson.

An Instrument for determining Spherical Triangles by Mechanical action. Mr. F. C. Penrose.

Note on the two exterior Satellites of *Uranus*. Rev. T. W. Webb.

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May 12. On our Sidereal System, and the Direction and Distance to its Centre. Mr. J. Ennis.
Note on the Conjunction of *Venus* and λ *Geminorum* on August 17–18, 1876. Mr. Dunkin.
On recent American determinations of Geographical positions in the West Indies and Central America. Major H. S. Palmer.
A Catalogue of red double Stars. Mr. S. W. Burnham.
Observations of Minor Planets made at the Observatory of Marseilles. M. E. Stephan.
Note on the Discovery and Observations of Minor Planets (160) to (163). Mr. Dunkin.
Note on Coggia's Comet (III. 1874). Mr. J. Dreyer.
On the relative Power of Achromatic and Reflecting Telescopes. Dr. T. R. Robinson.
Note on the Satellites of *Uranus*. Mr. E. Neison.
Note on Dr. Royston Pigott's Starlit Transit Eyepiece. Capt. W. Noble.
Visibility of *Oberon* and *Titania*. Mr. Rogerson.
On Lohrmann's and Schmidt's Lunar Maps, and Note on a new red Star. Mr. J. Birmingham.
Spectroscopic results for the Motions of Stars in the line of sight made at the Royal Observatory, Greenwich. The Astronomer-Royal.
Note on the Displacement of Lines in the Spectra of Stars. Mr. W. H. M. Christie.
On Precession. Dr. Berg.
On the Transit across the Sun's disk of the second, or great Comet of 1819. Mr. J. R. Hind.

June 9. On the Atmosphere of *Venus*. Mr. E. Neison.
Remarks in connection with his five volumes of Solar drawings. Rev. F. Howlett.
On the Determination of the Distances of a Comet from the Earth from three Observations. Dr. Berg.
Visibility of *Mercury* and *Venus* in sunshine. Mr. W. F. Denning.
Elements of Minor Planets (161), (162) and (163). Mr. Dunkin.
On a hitherto unnoticed apparent inequality in the Longitude of the Moon. Prof. S. Newcomb.
Photometric experiments upon the Light of *Venus*. Mr. J. I. Plummer.
Observations of *Venus*. Capt. W. Noble.
On the proper Motion of the bright Spots on *Jupiter*. Mr. J. Brett.
Note on a method of obtaining Equatoreal Motion on an Altazimuth Stand. Lord Lindsay.
Note on a Double Image Spectroscope. Lord Lindsay.

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Nov. 10. Measurement of the direct Effects of Sun-spots on Terrestrial Climates. Prof. Langley.

Observations of Planets with the Transit Circle at Dublin (Dunsink). Dr. R. Copeland.

Observations of Lunar Eclipse of 1876, September 3, made at Cadiz. Señor A. T. Arcimis.

A method of deducing the Formula for correcting the Computed Time of an observed Occultation for errors in the Elements adopted. Mr. W. H. Finlay.

Description of an Improved Altazimuth Stand for Reflecting Telescopes, with a new form of Binocular Eye-piece. Mr. W. H. Thornthwaite.

Spectroscopic observations of the Motions of Stars and of *Venus* in the line of sight, and of the rotation of the Sun and of *Jupiter*, made at the Royal Observatory, Greenwich. The Astronomer-Royal.

On the effect of wear in the Micrometer Screws of the Greenwich Transit Circle. Mr. W. H. M. Christie.

Observations of the Solar Eclipse of 1876, Sept. 17. Mr. J. Tebbutt.

An endeavour to simplify the method of making the correction for the Spheroidal figure of the Earth in Lunar observations, and particularly with reference to its effects upon the Lunar Distance. Mr. F. C. Penrose.

Dec. 8. A List of Binary and other interesting Double Stars. Messrs. J. M. Wilson and J. Gledhill.

On some phenomena of the Internal Contacts common to the Transits of *Venus*, observed in 1769 and 1874, and some remarks thereon. Mr. E. J. Stone.

On some diffraction Experiments of M. Ch. André, with reference to Astronomical Instruments, and the general theory of this Diffraction. Rev. S. J. Perry.

On the Phenomena exhibited by a Planet in its transit across the Solar disk, from observations by M. Ch. André. Rev. S. J. Perry.

Note on the relative Space-penetrating power of the Pulkowa 15-inch Refractor, and Mr. Lassell's 4-foot Reflector. M. O. Struve.

On an Oversight in the "Mécanique Céleste," and on the Internal Densities of the Planets. Mr. G. H. Darwin.

On the Error of the tabular place of *Venus* on December 8, 1874. Col. Tennant.

Note on the Gradation of Light on the disk of *Venus*. Mr. W. H. M. Christie.

On the Position of the point of maximum brightness on *Venus*. Mr. E. Neison.

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Note on Professor Langley's paper on the Direct Effects of Sun-spots on Terrestrial Climates. Mr. W. Mattieu Williams.

1877.

Jan. 12. On the Orbit of *α Centauri*. Mr. A. Marth.

On the Conjunction of *Venus* and λ *Geminorum*. Mr. J. I. Plummer.

Theory of the Horizontal Photoheliograph, including its application to the determination of the Solar Parallax by means of Transits of *Venus*. Prof. Harkness.

On O. M. Mitchell's Observations at Cincinnati. Prof. Cleveland Abbe.

Observations of Shooting Stars, April to December, 1876. Mr. W. F. Denning.

Note on an Improved Mode of viewing the Sun. Dr. W. Erck.

Observations of Occultations of Stars by the Moon, and phenomena of *Jupiter's* satellites, made at the Royal Observatory, Greenwich, in the year 1876. The Astronomer-Royal.

Micrometical Measures of Double Stars. Mr. G. Knott.

Ephemeris for determining the positions of the satellites of *Uranus*. Mr. A. Marth.

On the Orbit of *α Centauri*. Mr. J. R. Hind.

The Specular Reflection hypothesis, and its bearing on the Transits of *Venus*. Mr. J. Brett.

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List of Public Institutions and of Persons who have contributed to the Society's Library &c. since the last Anniversary.

Her Majesty's Government.
Her Majesty's Government in India.
Her Majesty's Government in Australia.
The Lords Commissioners of the Admiralty.
The Government of Prussia.
The Government of the United States of America.
The Meteorological Office.
Royal Society of London.
Royal Society of Edinburgh.
Royal Geographical Society.
Royal United Service Institution.
Royal Irish Academy.
Royal Dublin Society.
Royal Asiatic Society of Great Britain.
Royal Asiatic Society of Bombay.
Royal Society of New South Wales.
Royal Society of Tasmania.
Asiatic Society of Bengal.
Belfast Natural History and Philosophical Society.
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British Horological Institute.
Council of the City of Manchester.
Geological Society.
Literary and Philosophical Society, Leeds.
Literary and Philosophical Society, Liverpool.
Literary and Philosophical Society, Manchester.
Philosophical Society, Glasgow.
Meteorological Society.
Photographic Society.
Physical Society of London.
Rugby School Natural History Society.
Society of Arts.
Zoological Society of London.
Royal Observatory, Greenwich.
Royal Observatory, Cape of Good Hope.
Radcliffe Observatory, Oxford.
Kew Observatory.
Imperial Observatory, Berlin.
Imperial Observatory, Vienna.
National Observatory, Paris.

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Observatory, Cincinnati.
Observatory, Coimbra.
Observatory, Collegio Romano.
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Observatory, Munich.
Observatory, Prague.
Observatory, Strasburg.
Observatory, Sydney.
United States Naval Observatory, Washington.
Imperial Academy of Sciences, Berlin.
Imperial Academy of Sciences, St. Petersburg.
Imperial Academy of Sciences, Vienna.
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Academy of Sciences, Buda-Pesth.
Academy of Sciences, Copenhagen.
Academy of Sciences, Göttingen.
Academy of Sciences, Montpellier.
Academy of Sciences, Munich.
Academy of Sciences, Stockholm.
Academy of Sciences, Turin,
Italian Society of Sciences, Rome.
Pontifical Academy de Lincei.
Society of Sciences, Batavia.
Society of Sciences, Bordeaux.
Society of Sciences, Cherbourg.
Society of Sciences, Helsingfors.
Society of Sciences, Leipsig.
Society of Sciences, Zurich.
Mathematical Society of France.
Museo Fisico, Florence.
Musée Teyler, Leyden.
Bureau des Longitudes.
Dépôt Général de la Marine.
Imperial University of Kasan.
Italian Spectroscopic Society.
Astronomische Gesellschaft, Leipsig.
Berlin Physical Society.
International Committee of Weights and Measures.
Smithsonian Institution, Washington.
American Academy of Sciences.
American Philosophical Society.
American Bureau of Navigation.
Franklin Institute, Philadelphia.

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Editors of the American Journal of Science and Arts.
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Editor of Bulletin des Sciences Mathématiques, &c.
Editor of the English Mechanic.
Editor of the Naturforscher.
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Editor of the Revue Scientifique.
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Prof. C. A. Young.
Prof. K. W. Zenger.

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The Meeting then proceeded to the election of the Officers and Council for the ensuing year, when the following Fellows were elected :—

President.

William Huggins, Esq., D.C.L., LL.D., F.R.S.

Vice-Presidents.

J. C. Adams, Esq., M.A., LL.D., F.R.S., Lowndean Professor of Astronomy, Cambridge.
Sir G. B. Airy, K.C.B., M.A., LL.D., D.C.L., F.R.S., Astronomer-Royal.
Arthur Cayley, Esq., M.A., LL.D., F.R.S., Sadlerian Professor of Pure Mathematics, Cambridge.
Edwin Dunkin, Esq., F.R.S.

Treasurer.

Samuel Charles Whitbread, Esq., F.R.S.

Secretaries.

J. W. L. Glaisher, Esq., M.A., F.R.S.
A. Cowper Ranyard, Esq., M.A.

Foreign Secretary.

Lord Lindsay, M.P.

Council.

John Brett, Esq.
W. H. M. Christie, Esq., M.A.
Warren De La Rue, Esq., M.A., D.C.L., F.R.S.
J. R. Hind, Esq., F.R.S., Superintendent of the *Nautical Almanac*.
E. B. Knobel, Esq.
George Knott, Esq.
William Lassell, Esq., LL.D., F.R.S.
E. Neison, Esq.
Captain William Noble.
Rev. S. J. Perry, F.R.S.
Earl of Rosse, B.A., D.C.L., F.R.S.
Captain G. L. Tupman, R.M.A.

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ADDENDUM.

The Suspected Intra-Mercurial Planet.

The Astronomer Royal has requested me to append to the Annual Report of the Council the following letter recently received from M. Le Verrier, relating to the approaching possible conjunction of the supposed intra-Mercurial planet with the Sun on March 21, 22, and 23 next. It is of extreme importance that a *continuous* scrutiny of the solar disk should be kept up, both in the northern and southern hemispheres, during these three days, as after 1877 no other opportunity will be afforded for many years of observing a possible transit of the planet. The Sun's disk should therefore be watched for a small planet at every two hours or more on the three days mentioned above. Photographs should be obtained when practicable, as they are far preferable to eye-views. E. DUNKIN.

PARIS: 15 *Février* 1877.

"MONSIEUR ET HONORÉ COLLÈGUE,

"Vous n'aurez pas oublié qu'au commencement de l'automne dernier une discussion s'éleva des observations faites à diverses époques et attribuées aux passages d'une ou de plusieurs planètes sur le disque du Soleil.

"Après une élimination attentive des observations inconciliables, il fut reconnu que cinq observations pouvaient effectivement appartenir aux passages d'une planète sur le disque du Soleil, savoir :—

Fritsch	1802	Octobre 10
Decuppis	1839	Octobre 2
Sidebotham	1849	Mars 12
Lescarbault	1859	Mars 26
Lummis	1862	Mars 20.

(*Comptes Rendus de l'Académie*, 2 Octobre 1876, p. 649.)

"Il parut dès lors difficile d'admettre que des observateurs qui n'avaient eu aucune relation entre eux, ni aucune connaissance des périodes en discussion, fussent ainsi tombés par hasard sur cinq époques précises d'un phénomène explicable par le mouvement d'une même planète.

"Le savant directeur du *Nautical Almanac*, M. Hind, ajouta beaucoup à l'autorité de ces conclusions, en montrant qu'une sixième observation (Stark, 1819, Octobre 9) était également représentée par la même orbite. (*Comptes Rendus*, 30 Octobre 1876, p. 809.)

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" Les passages de la planète offrent des périodes comme tous les phénomènes du même genre.

" Il a été établi qu'elle sera en conjonction avec le Soleil le 22 Mars prochain. Malheureusement les incertitudes qui règnent sur la position du nœud et la valeur de l'inclinaison ne permettent pas de décider si la planète passera précisément sur le disque du Soleil; et l'on peut même affirmer qu'après 1877 il s'écoulera plusieurs années avant qu'un passage soit possible. Dans cette situation, les astronomes estimeront, sans doute, qu'il importe d'observer très attentivement le Soleil les 21, 22 surtout, et 23 Mars prochain.

" Veuillez agréer, Monsieur et honoré collègue, l'assurance de mes sentiments dévoués.

" LE VERRIER."

It may be remarked that telegrams on this subject have been forwarded by the Astronomer Royal to Dr. Hector, at Wellington, and to Dr. Haast, at Canterbury, New Zealand; to Mr. Ellery, at Melbourne; to Mr. Russell, at Sydney; to Mr. Todd, at Adelaide; and to Mr. Pogson, at Madras. E. D.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. MARCH 9, 1877. No. 5.

PROFESSOR A. CAYLEY, F.R.S., Vice-President, in the Chair.

John Rand Capron, Esq., Guildown, Guildford, Surrey;
Dr. William Evans, Llanerchymedd, Anglesey;
Frank McClean, Esq., M.A., 23 Great George Street, Westminster; and
R. Meldola, Esq., F.C.S., 23 John Street, Bedford Row;

were balloted for and duly elected Fellows of the Society.

The Nebula in Orion—Request to Astronomers.

(*Communicated by E. B. Knobel, Esq.*)

I am engaged in observations of the central portions of the Nebula of *Orion*, and desire to compare all former drawings, both ancient and modern. I have in my possession the following published drawings of it:—

1656, Huyghens; 1673, Picard; 1731, Mairan; 1742, Long; 1758, Le Gentil (2); 1771, Messier; 1774, W. Herschel; 1779, Lefebvre; 1794, Schroeter; 1797–8, Schroeter (4); 1824, J. Herschel; 1837, J. Herschel; 1837, Lamont; 1839, De Vico; 1841, Rondoni (2); 1847, Lassell; 1848, W. C. Bond (2); 1854, Lassell; 1862, Liaponoff and Struve; 1862, Secchi; 1862, Tempel; 1865, G. P. Bond; 1867, Lord Rosse; 1868, Secchi; 1872, D'Arrest; 1874, Winlock and Trouvelot; 1875, Holden and Trouvelot.

Through the courtesy of the various authors, I have original (unpublished) sketches, or elaborate drawings, made by Cooper (?); Schmidt, 1861 (2); Lassell, 1862; and Trouvelot, 1875.

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I shall be most grateful for notice of any drawing not mentioned in the above list, whether published or unpublished, or for a reference to unpublished observations of this object, particularly of the central nebulous portions.

EDWARD S. HOLDEN.

United States Naval Observatory, Washington,
1877, January 31.

The Approaching Opposition of Mars—Request to Astronomers.

M. F. Terby, Doctor of Science, Louvain, Belgium, invites observers, particularly those in the equatoreal and southern regions, to make a large number of drawings of the planet *Mars* during the remarkable opposition of the present year, 1877. He recalls to them that he has published a Memoir, entitled "Aréographie, ou étude comparative des Observations faites sur l'aspect de la planète *Mars* depuis Fontana (1636) jusqu'à nos jours," t. xxxix. *Mem. Cour.* (4°) de l'Acad. R. de Belgique. This Memoir contains a large number of questions, which might be answered by the observers in the opposition of 1877; these refer to the principal doubtful points in Mr. Proctor's Chart. M. Terby begs the astronomers who have hitherto kindly communicated to him their observations to send him also their drawings of 1877; he hopes thus to perfect Mr. Proctor's already so excellent chart.

The Dunecht Observatory Publications.

Mr. Ralph Copeland writes to correct an error occurring in *Monthly Notices*, p. 199, where it is stated that the arrangement and reduction of vol. i. of the Dunecht Observatory Publications were performed by him. Although he is responsible for the general arrangement of the work, yet the whole of the computations were performed by Mr. Robert Copeland, of Manchester.

On Apparent Brightness as an Indication of Distance in Stellar Masses. By E. J. Stone, M.A., F.R.S., Her Majesty's Astronomer, Cape of Good Hope.

In the important investigations of the motion of the solar system in space by O. Struve and Airy, the distribution of the stellar distances has been made in accordance with the views of W. Struve. The correctness of these views has, from time to time, been questioned. It may have been shown that some

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astronomers have attached undue importance to the numerical accuracy of the results obtained by W. Struve; but I cannot consider that the average distribution of the distances of stars according to apparent brightness has been, or indeed ever will be, disproved. I do not know that there is much novelty in my views, but the subject presents itself to my mind in the following way. It is certain that the apparent brightness of a star will, *cæteris paribus*, vary inversely as the square of its distance from us; and an inspection of any table of annual parallaxes will prove that we have around us ample space for very considerable variations in the magnitudes of stars from the sole effects of distance.

The following table, extracted from Herschel's *Outlines of Astronomy*, will be sufficient for my present purpose:—

Star's name.	Annual parallax.
	″
α Centauri	0·976
61 Cygni	0·348
α Lyræ	0·155
Sirius	0·150
1830 Groombridge	(0·71) doubtful
ι Ursæ Majoris	0·133
Arcturus	0·127
Polaris	0·067
Capella	0·046

Without attaching undue importance to the numerical accuracy of the smaller values, we have here a proved range of stellar distances in at least the proportion of 1 to 10. It is certain, therefore, that our brightest stars might be changed to stars of about the tenth magnitude by a mere shift of our relative position in space. But there are not the slightest grounds for our supposing that the relative distance of the stars from us is restricted to any such proportions as 1 to 10. Such a proportion merely marks the limit beyond which we cannot discriminate with much certainty between the distances of the stars. Annual parallaxes of less than a tenth of a second of arc are sensibly equal, because the limit of our present power of accurate measurement has been nearly reached. If we assume, therefore, that the magnitudes of the stars depend chiefly upon their distances from us, our assumption rests upon a *vera causa*, and we have independent proof of the sufficiency of the assumed cause to produce the observed differences in stellar magnitudes.

But I think it may be shown that such an assumption is not a mere barren hypothesis. I know of no more striking fact in Astronomy than the rapid increase in the number of the stars as we proceed down the scale of magnitudes. Every increase of

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optical power appears only to bring this fact into greater prominence.

If we accept distance as the principal factor in determining stellar magnitudes, the rapid increase in the number of the fainter stars not only becomes intelligible, but is a necessary consequence of our assumption on the most general distribution of stellar masses which we can conceive.

Suppose that there are n different degrees of intrinsic brightness in the stars around us. Suppose, for the purposes of numerical illustration, that we have over any surface these classes of stars distributed in any definite proportions. Since the brightness of a star is classed under discontinuous magnitudes, we can logically suppose, for our present purpose, that the stellar distribution is discontinuous also over the surfaces of small portions of spheres whose radii are such that a star shifted from one surface to the next would be changed one magnitude. With such a distribution of stars, without any assumptions of uniform distribution in all directions or at all distances, and with any proportions amongst the stars of different intrinsic brightness which could be admitted as probable, the large increase in the number of the fainter stars becomes a necessary consequence of the supposed distribution. I shall, however, for simplicity, introduce the conditions that the stars of different intrinsic brightness are to be supposed equally distributed, and their number in any given direction proportional to the area over which they are distributed. Such conditions are certainly not strictly true, and so far as they are untrue their tendency will be to make the results of the computations based upon them differ from the results of observation; but on the large average these conditions are probably close approximations to the truth. Through our position conceive a cone of small solid angle to be drawn in any direction. Let $x_1, x_2 \ldots x_n$ be the radii of the spheres which cut the cone at distances such that a star would be changed one magnitude by being shifted from one of the surfaces to the consecutive surfaces; x_1 being such a distance that the stars of the first degree of intrinsic brightness will at that distance appear stars of the first magnitude. Then, if $ds_1, ds_2, \ldots ds_n$ are the portions of the spheres intercepted by the cone, the number of the stars of the different magnitudes in the direction under consideration will be—

1st magnitude number = C (some constant).

2nd " " $= C\left(1 + \frac{ds_2}{ds_1}\right)$.

3rd " " $= C\left(1 + \frac{ds_2}{ds_1} + \frac{ds_3}{ds_1}\right)$.

nth " " $= C\left(1 + \frac{ds_2}{ds_1} + \frac{ds_3}{ds_1} + \frac{ds_4}{ds_1} + \cdots + \frac{ds_n}{ds_1}\right)$;

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for stars of the first degree of intrinsic brightness only appear of the first magnitude when found on ds_1; of the second magnitude on ds_2; and of the nth on ds_n.

Stars of the second degree of intrinsic brightness appear of the second magnitude on ds_1; of the third on ds_2; and of the $(n+1)$th on ds_n. Stars of the third degree of intrinsic brightness appear of the third magnitude on ds_1; of the fourth magnitude on ds_2, &c.

Consequently, therefore, since a similar result holds in all directions, we have generally the number of nth magnitude stars

$$= A\left(1 + \frac{ds_2}{ds_1} + \frac{ds_3}{ds_1} + \ldots + \frac{ds_n}{ds_1}\right)$$

$$= A\left(1 + \left|\frac{x_2}{x_1}\right|^2 + \left|\frac{x_3}{x_1}\right|^2 + \ldots + \left|\frac{x_n}{x_1}\right|^2\right).$$

It remains to determine the numerical values of the ratios involved.

In Sir J. Herschel's volume of Cape Observations will be found some experiments showing that, if the double star α *Centauri* be taken as the standard, the brightness of stars of the first four magnitudes of the ordinary scale are very approximately

$$= \frac{1}{(1{\cdot}414)^2} \text{ for 1st magnitude stars.}$$

$$= \frac{1}{(2{\cdot}414)^2} \text{ for 2nd } \quad ,, \quad ,,$$

$$= \frac{1}{(3{\cdot}414)^2} \text{ for 3rd } \quad ,, \quad ,,$$

$$= \frac{1}{(4{\cdot}414)^2} \text{ for 4th } \quad ,, \quad ,,$$

Such a scale will not, however, be true for the fainter stars.

In the introduction to Carrington's *Redhill Catalogue of Stars*, there are some results of experiments with varying apertures, showing that from the fifth to the ninth magnitude of the ordinary scale the brightness of each magnitude is fairly represented by the relation

Brightness of nth magnitude $= 2{\cdot}75 \times$ that of $(n+1)$th.

I shall exhibit the proportional number of the stars of different magnitudes when the ratios of $\frac{x_n}{x_1}$ are determined with both these light ratios. We must expect, if the supposed distribution is any close approximation to the truth, to find that the computed numbers will agree with the observed numbers, for the first four magnitudes better with Herschel's scale, and for the last five magnitudes better with Carrington's scale,

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With Herschel's scale

$$\left|\frac{x_n}{x_1}\right|^2 = \left(\frac{n\cdot414}{1\cdot414}\right)^2;$$

And the number of nth magnitude stars

$$s_n = \frac{CA}{(1\cdot414)^2}\{(1\cdot414)^2 + (2\cdot414)^2 + \cdots + n\cdot414)^2\};$$

$$s_n = C\left(\frac{n^3}{3} + 0\cdot914\,n^2 + 0\cdot752\,n\right).$$

Next, assuming Carrington's light ratio, we have

$$s_n = C\{1 + 2\cdot75 + (2\cdot75)^2 + \cdots + (2\cdot75)^{n-1}\};$$

$$s_n = C\frac{(2\cdot75)^n - 1}{1\cdot75}.$$

The following Table exhibits certain numbers attributed to Argelander and the results of the two formulæ. The number of first magnitude stars is made equal for the purposes of comparison :—

Mag.	Argelander's numbers.	Computed numbers Herschel's scale.	Computed numbers Carrington's scale.	Mean of Compd.
1	20	20	20	20
2	65	78	75	76
3	190	195	226	210
4	425	390	642	516
5	1,100	683	1,786	1,234
6	3,200	1,094	4,931	3,012
7	13,000	...	13,581	...
8	40,000	...	37,360	...
9	142,000	...	102,780	...

It will be seen that the numbers based on Herschel's scale do agree best for the first four magnitudes, and those based on Carrington's scale best for the fainter magnitudes; whilst a mean between the two agrees best with the observed numbers for the end of Herschel's and the commencement of Carrington's scale. This is what might have been expected. The computed number of stars of the ninth magnitude falls short of the observed number by forty thousand; but when it is considered that this discrepancy is not greater than would arise from an uncertainty of estimation of about a tenth of a magnitude at the end of the scale, the agreement between the computed and observed numbers will, I think, be considered sufficiently close to prove that the supposed distribution of the stars must be a somewhat close approximation to the truth.

If the distribution which I have supposed be any close

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approximation to the truth, the average distances of the fainter stars must be greater than those of the brighter stars; but it by no means follows that any one faint star is further from us than any one much brighter star. In fact, the supposition made has been that stars of all magnitudes may exist at all stellar distances.

On Observations of Contacts of the Limb of Venus, or Mercury, with that of the Sun. By Prof. Simon Newcomb.

During the past four years, I have had occasion to give some attention to the problem of obtaining accurate observations of the various phases of contact between the limb of an interior planet and that of the Sun. My views, as now presented, have been derived from the study of an artificial representation of a transit of *Venus*, aided by general considerations on the subject, and by the opinions and investigations of others. I am induced to present them at the present time by the researches of M. André, and the papers of Mr. Stone and Father Perry in the *Monthly Notices* for December last.

(1) If I might be allowed to criticise certain of the views of others in a general way, I should say that one defect of much of the reasoning on this subject is this: it has too generally been assumed that the geometric outlines of *Venus* and the Sun, considered as mathematical lines, can be noted in observation with the same sort of definiteness and precision as that with which the mind conceives them; and sufficient attention has not been paid to the practical difficulties which the eye meets with in representing this geometric conception. I conceive that the question whether a certain phase can or cannot be definitely distinguished and observed by the eye is to be settled by actual trial, and by a consideration of the imperfections of vision, rather than by a consideration of its purely geometric definiteness of form.

(2) One result of the trials with the artificial transit is, that there is a certain phase near that of external contact which can be observed with the same order of precision as the internal contact, provided that the proper conditions are fulfilled. Among these conditions are, that the observer shall previously have practised on the artificial transit; that he shall know at exactly what point of the Sun's limb to look for the first contact; that he shall know when to look for the contact with an uncertainty of not much less than half a minute, nor much more than a minute; and that he shall have a telescope of fixed size and power. Of course the phase thus observed will not be geometric contact, but that occurring at the time when the notch in the Sun's limb first becomes visible. This phase varies much less with variations in the atmospheric condition and in the size and power of the telescopes than might have been supposed.

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(3) The phase of external contact at egress is more uncertain than at ingress, owing to the doubt of the observer as to whether the notch has or has not disappeared from his view; that doubt extending over a longer period than the doubt as to when he first sees the notch at ingress.

(4) Referring now to the spectroscopic observation of the external contact, and to Father Perry's suggestion for rendering the projection of the planet on the chromosphere visible by means of a coloured glass in order to observe this contact, which two methods are the same with respect to the optic phenomena designed to be produced, I do not think it possible to obtain a precise observation in either of these ways. The phenomenon to be observed would then be the contact of a dark limb (that of the planet) with an adjacent bright limb (that of the Sun), on a background intermediate in tint (that of the chromosphere). The result must then depend very largely on the amount of irradiation, and on the observer's acuteness of vision in seeing the slowly diminishing line of chromosphere between the planet and the Sun. The planet will, in reality, be invisible: all the observer can see will be the outline of the chromosphere, as cut out by the planet; and when the latter gets so near the limb of the Sun that the chromosphere itself is invisible—owing to the overpowering brightness of the Sun's limb—the outline of the planet can no longer be traced, and will not reappear until it is seen projected on the background of the Sun itself. I conceive, therefore, that any attempt to make different observers certainly note the same phase of such a phenomenon will result in failure. It would, however, be of interest to try the method artificially.

(5) In describing the phenomena near the time of internal contact, I shall consider the planet to be approaching egress. For reasons which I shall soon mention, the artificial transit was placed at a distance of about eleven hundred yards from the place of observation, so that a greater or less amount of atmospheric undulation was always present. Supposing, then, that the planet was approaching the Sun's limb, and the thread of light growing thin, owing to the approach of contact, the first thing which an observer would remark was that, in consequence of the constant changes of outline caused by atmospheric disturbance of the images, no set of phenomena could be described as invariable. It would be necessary to combine judgment with sight, by considering what might be called a *mean* phenomenon. Different observers might form different judgments as to what this mean phenomenon was. It would, however, always be seen that as the thread of light became quite thin, it looked darker than the rest of the Sun; and unless the atmosphere was more steady than is usual in the day-time, the line of light would occasionally be broken up into two or more very irregular threads or twists of light, which would gradually grow fainter until they would occasionally almost disappear from view. Repeated trials showed that the time of true internal contact was marked by the moment at which light entirely ceased to glimmer across the dark space

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formed by the approach of the limb of the planet to that of the Sun.

(6) Every attempt to estimate an apparent contact, or moment at which the limbs of *Venus* and the Sun were tangent to each other, without reference to the appearance of the thread of light, was a total failure. It was, in fact, impossible to make any such estimate without an uncertainty of half a minute or more. This will not appear surprising if we reflect that the outlines of *Venus* and the Sun cannot present themselves to the vision as geometric lines, but only as more or less indefinite edges of a visible surface of sunlight; which visible surface disappears most gradually near the region of contact, and, in fact, at the moment of ideal "apparent contact" cannot be seen at all at the point of contact. Anyone who wishes to satisfy himself on this point has only to examine a series of figures in which the black drop is represented, and try to decide which of them represents apparent contact. If he wishes to come as near nature as possible, he must shade off the outlines both of *Venus* and the Sun, so that they shall terminate in a soft border, and view the picture through a rising current of hot air.

(7) Any artificial representation of these phenomena, in which the bright surface of the Sun is surrounded by a dark background, must fail to be correct in a very important particular. As a matter of fact, we know that the atmosphere immediately around the Sun's limb is of dazzling brilliancy. In meridian observations of the Sun, when the light is so cut down by a dark glass as no longer to dazzle the eye, the five spider-lines are visible on the background of the atmosphere; else it would be impossible to observe the transit of the Sun's first limb. This brilliancy of the atmosphere must greatly diminish irradiation; and if the Sun is observed through haze (as must often be the case in observations of contact when the Sun is near the horizon), irradiation may be entirely destroyed. It will therefore be impossible to observe an actual internal contact of *Venus* or *Mercury* with a precision corresponding to that of an artificial contact on a black background.

(8) The atmosphere affects the phenomena of contact in three ways:—

α. By illuminating the background as just described.

β. By producing undulations in the outlines of the images, thereby preventing the phenomena from being invariable.

γ. By softening the outlines of the Sun's limb, and thus rendering it more or less indefinite.

The artificial transit to which I have alluded was placed at a distance, in order that all these effects might be produced and studied; otherwise, the optic phenomena of contact may be entirely different. For instance, because the black drop is sharply seen in the artificial transit when the background is quite black, it does not follow that it will be noticed in the actual transit.

(9) A good idea of many of the causes of uncertainty to

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which I have alluded may be formed by examining a series of photographs of internal contact taken by the Janssen process. One will immediately appreciate the distinction on which I have insisted, between geometric lines on the one hand and the outlines of *Venus* and the Sun on the other.

(10) I have said little of the black drop; partly because I do not think there can be much room for a real difference of opinion respecting its nature and causes, and partly because the question whether it is seen is of entirely secondary importance, except as affording some indication of the sharpness of definition. In looking at the artificial transit, it was very easy, about the moment of internal contact, by taking a general mean outline of the undulating image of the planet, and imagining that outline continued across the undulating line of light and darkness mixed, into which the ideal thread was reduced by the imperfections of vision, to see something like a black drop. On the other hand, another observer, with his attention fixed solely on the thread of light, would see nothing of the sort. The final disappearance of the thread of sunlight being the only phase which can be actually observed, an observer fixing his attention exclusively on this would not see any black drop at all, unless the amount of irradiation was exceptionally great.

(11) I see little or nothing in Mr. Stone's views radically inconsistent with those which I have here set forth. His remark on his observation of the egress of *Venus* in 1874, "the apparent contact was rendered more difficult than would otherwise have been the case by the appearance of this ligament, or, in other words, by the disappearance of a sensible portion of the Sun's limb near the point of contact," is in entire accord with the views I have expressed in paragraph 6.

(12) The general conclusion to which I am led is that there is but one phase of each contact which can be observed with any approach to accuracy, namely:—

α. The time when the notch made by *Venus* advancing on the Sun becomes visible.

β. The time at which true sunlight is first seen all the way around the following limb of the planet.

γ. The planet approaching egress, the time when it first completely cuts off the true limb of the Sun, and the space connecting the limb of the planet with the sky becomes as dark as the planet itself.

δ. The time when the last limb of the planet, leaving the limb of the Sun, disappears from view.

If an observer, at the time of internal contact, does not note, or try to note, the phases β and γ, there is no definite phase to which his observation can be referred. The old notion that at second internal contact there is a sudden formation of the black drop, which marks the moment of true contact, has been so completely exploded that it needs no further refutation. The more clear and dark the atmosphere around the Sun, the more rapidly

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will contact appear to form, whether a black drop is seen or not; but under no circumstances under which an actual transit is likely to be observed for parallax will it be really sudden. When it appears so it is only because the observer failed to notice the gradual darkening and breaking up of the thread of light. From the commencement of this darkening and diffusion, until the "apparent contact," which comes last of all, there are a series of progressive changes, which may extend over a period ranging anywhere from twenty or thirty to ninety seconds, at any point of which a random observation of internal contact may fall. The worse the definition, and the lower the planet, the greater the range; but the time of true contact is always near the mean of the period.

Washington,
1877, *February* 22.

Ephemeris for Physical Observations of Jupiter 1877.

By Mr. A. Marth.

Greenwich Noon. 1877.	Angle of position of ♃'s Axis.	Longitude of ♃'s Meridian directed to the Earth.	diff.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax.		Equatoreal Diameter.
	°	°	°	°	°	°	°	″
Mar. 31	357·72	104·8		−2·31	−2·45	−10·81		38·71
			4353·1				+ ·14	
Apr. 5	357·59	137·9		2·31	2·43	10·67		39·33
			3·2				·21	
10	357·51	171·1		2·30	2·42	10·46		39·96
			3·3				·29	
15	357·46	204·4		2·30	2·41	10·17		40·59
			3·3				·37	
20	357·44	237·7		2·29	2·39	9·80		41·22
			3·4				·45	
25	357·46	271·1		2·29	2·38	9·35		41·85
			3·5				·53	
30	357·52	304·6		2·29	2·37	8·82		42·46
			3·5				·61	
May 5	357·61	338·1		−2·28	−2·35	−8·21		43·04
			3·6				·67	
10	357·74	11·7		2·28	2·34	7·54		43·60
			3·6				·75	
15	357·90	45·3		2·28	2·32	6·79		44·13
			3·6				·82	
20	358·09	78·9		2·28	2·31	5·97		44·60
			3·7				·87	
25	358·31	112·6		2·28	2·30	5·10		45·03
			3·7				·93	
30	358·55	146·3		2·28	2·28	4·17		45·40
			3·7				·97	
June 4	358·82	180·0		−2·28	−2·27	−3·20		45·69
			3·7				1·01	
9	359·10	213·7		2·28	2·25	2·19		45·92
			3·7				1·03	

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Greenwich Noon. 1877.	Angle of position of ♃'s Axis.	Longitude of ♃'s Meridian directed to the Earth.	diff.	Latitude of Earth above ♃'s Equator.	Latitude of Sun above ♃'s Equator.	Annual Parallax.		Equatoreal Diameter.
	°	°	°	°	°	°	°	″
June 14	359·39	247·4		2·28	2·24	1·16		46·07
			3·7				1·04	
19	359·68	281·1		2·28	2·22	−0·12		46·14
			3·6				1·05	
24	359·98	314·7		2·28	2·21	+0·93		46·13
			3·6				1·04	
29	0·28	348·3		2·27	2·19	1·97		46·05
			3·5				1·01	
July 4	0·56	21·8		−2·27	−2·18	+2·98		45·88
			3·5				·99	
9	0·83	55·3		2·26	2·16	3·97		45·64
			3·4				·95	
14	1·08	88·7		2·26	2·15	4·92		45·33
			3·3				·89	
19	1·31	122·0		2·25	2·13	5·81		44·95
			3·2				·84	
24	1·51	155·2		2·24	2·12	6·65		44·52
			3·1				·77	
29	1·68	188·3		2·23	2·10	7·42		44·04
			3·1				·71	
Aug. 3	1·82	221·4		−2·22	−2·08	+8·13		43·53
			2·9				·64	
8	1·93	254·3		2·21	2·07	8·77		42·97
			2·8				·56	
13	2·00	287·1		2·20	2·05	9·33		42·40
			2·8				·48	
18	2·03	319·9		2·19	2·03	9·81		41·80
			2·6				·40	
23	2·03	352·5		2·18	2·02	10·21		41·20
			2·6				·33	
28	1·99	25·1		2·17	2·00	10·54		40·59
			2·5				·25	
Sept. 2	1·91	57·6		−2·15	−1·98	+10·79		39·98
			2·4				·17	
7	1·80	90·0		2·14	1·97	10·96		39·38
			2·3				·10	
12	1·66	122·3		2·12	1·95	11·06		38·78
			2·2				+ ·03	
17	1·48	154·5		2·11	1·93	11·09		38·20
			2·2				− ·04	
22	1·27	186·7		2·09	1·92	11·05		37·64
			2·1				·11	
27	1·03	218·8		2·07	1·90	10·94		37·10
			2·0				·17	
Oct. 2	0·76	250·8		−2·06	−1·88	+10·77		36·58
			2·0				·22	
7	0·46	282·8		2·04	1·86	10·55		36·08
			1·9				·28	
12	0·13	314·7		2·02	1·85	10·27		35·60
			4351·9				− ·34	
17	359·78	346·6		2·00	−1·83	9·93		35·15

Assumed daily rate of rotation 870°·60. The "annual parallax" is the difference of the Jovicentric longitudes of the Sun and Earth, reckoned in the plane of Jupiter's equator.

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The inclinations γ and the ascending nodes Γ of the orbits of the satellites in reference to the plane of *Jupiter's* equator are the following, the nodes being reckoned from the point of the vernal equinox of the planet:—

1877.	Sat. I.		Sat. II.		Sat. III.		Sat. IV.	
	γ_1	Γ_1	γ_2	Γ_2	γ_3	Γ_3	γ_4	Γ_4
	°	°	°	°	°	°	°	°
Mar. 1	0·0098	40·9	0·4510	49·52	0·1990	274·46	0·3298	330·54
Apr. 30	98	39·5	·4518	47·51	·1981	273·91	·3290	330·53
June 29	98	37·9	·4525	45·49	·1972	273·35	·3281	330·50
Aug. 28	98	36·2	·4532	43·47	·1964	272·80	·3274	330·45
Oct. 27	0·0098	34·5	0·4539	41·45	0·1956	272·24	0·3267	330·39

On Two Ancient Occultations of Planets by the Moon, observed by the Chinese. By J. R. Hind, F.R.S.

In the Appendix to the *Connaissance des Temps* for 1810 will be found a considerable number of observations taken from the Chinese astronomical records by the Jesuit missionary Gaubil, whose manuscript relative to the Chinese observations of comets was so much used by Pingré in the preparation of his *Cometographie*. Amongst the numerous occultations comprised in this list, there are two, and two only, in which the hour, or rather the particular two-hourly interval, at which the occultation took place is distinctly stated, and it is to these occultations that the present Note refers.

I have calculated the circumstances of these phenomena with the view to check a system of lunar motions previously applied in searching for the dates of several solar eclipses recorded on the Nineveh tablets, to which my attention had been directed by Mr. J. W. Bosanquet, and which, as compared with several historical total eclipses, of which the dates are well known, appeared to require but small modification. I have employed Damoiseau's Tables of 1824, adapting his main arguments to the results for secular motions &c. obtained by the Astronomer Royal from the discussion of the Greenwich lunar observations from 1750 to 1830, retaining the last values given by Hansen for terms depending on the square of centuries, which I had found to fit in best with the Greenwich motion proportional to time, at least as regards the secular acceleration. For the Sun and planets Le Verrier's Tables were adopted.

The earliest occultation recorded by Gaubil is one of the planet *Mars* by the Moon, and is thus translated:—

"Dynastie des Han occidentaux, la cour à Si-gan-fou du Chen-sy. An 69 (B.C) = 1re année *Ti-tsie*, 1re Lune, jour *vou-ou* (14 février) à la 2e veille de 9 à 11 heures du soir, la Lune éclipsa *Mars*, entre les constellations *Kio* et *Kang*."

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B.C. 69, February 14.

Paris M.T. h	Sun's True Longitude. ° ′ ″	Log. R.		
2	322 52 19·9	9·9979038	Sideral time at 0 h	21 h 23 m 31 s
6	323 2 16·9	9·9979208	Equation of time (Subtractive from Mean Time).	17 13

h	Mars' Helioc. Longitude. ° ′ ″	Mars' Helioc. Latitude. ° ′ ″	Mars' log. Rad. Vect.
2	166 58 50·5	+1 20 50·0	0·2062127
6	167 2 44·4	+1 20 44·7	0·2061696

h	Mars' Apparent R.A. ° ′ ″	Mars' Apparent Decl. ° ′ ″	
2	196 49 44	−4 20 44	Log. distance 9·90774.
6	196 49 51	−4 20 38	

h	Moon's R.A. ° ′ ″	Moon's Decl. ° ′ ″		
5	196 49 27	−3 46 31	Hor. Parallax	60 8·5.
6	197 23 58	−3 57 50	Semi-diameter	16 23.

I take the position of Si-gan-fou from M. Biot's *Dictionnaire des Noms Anciens et Modernes des Villes et Arrondissements de l'Empire Chinois*—

Long. 106° 37′ 45″ E. of Paris; Lat. 34° 16′ 45″;

and from the above data find a visible occultation :—

	h	m	
Immersion February 14 at	10	22	Apparent time at Si-gan-fou.
Emersion ,, ,,	10	59	

The immersion is therefore made to occur well within the two-hourly interval named in the Chinese annals, and the Moon was in *Virgo*, between the constellations *Kio* and *Kang*.

The second occultation to which I have referred is one of the planet *Venus*, thus given by Gaubil :—

"Dynastie des Tsin orientaux, la cour à Nanking, appelé alors Kien-Kang. An 361=5^{e} année, 1re Lune, jour *y-tcheou* (20 *Mars*) à l'heure *tchin* (temps de 7 à 9 heures du matin), la Lune éclipsa *Vénus* dans la constellation *Goey*."

Calculating in the same manner as before, I find the following figures :—

A.D. 361, March 19.

Paris M.T. h	Sun's True Longitude. ° ′ ″	Log. R.		
12	359 47 39·6	0·0018164	Sideral time at 0 h	23 h 49 m 28 s
13	359 50 6·2	0·0018113	Equation of Time (Subtractive from Mean Time).	7 49

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h	Venus' Heliocentric Longitude. ° ′ ″	Venus' Heliocentric Latitude. ° ′ ″	Venus' Logarithmic Radius Vector.
12	239 0 56·6	+0 9 55·5	9·8614762
13	239 4 54·3	+0 9 41·0	9·8614777

h	Venus' Apparent R.A. ° ′ ″	Venus' Apparent Decl. ° ′ ″	
12	317 36 26	−16 18 37	Log. distance 9·94883
13	317 39 14	−16 17 59	

h	Moon's R.A. ° ′ ″	Moon's Decl. ° ′ ″	
12	317 4 23	−15 45 55	Hor. Parallax 59 58
13	317 41 17	−15 38 21	Semi-diameter 16 20

Taking the position of Nanking from the *Connaissance des Temps*, a visible occultation again results:—

	h m	
Immersion, March 19 at	19 34	Apparent time at Nanking.
Emersion, ,, ,,	20 59	

Consequently the phenomenon occurred within "l'heure *tchin*," as recorded by the Chinese, and the Moon was at the time in the constellation named.

Note by the Astronomer Royal on the Numerical Lunar Theory.

In the *Monthly Notices of the Royal Astronomical Society* for 1874, January, vol. xxxiv., No. 3, I gave as the three equations of motion in the Lunar Theory the three following: (1) The equation of areas described by the radius vector parallel to the plane of the ecliptic; (2) The equation of *vis viva* parallel to the plane of the ecliptic; (3) The equation of motion perpendicular to the plane of the ecliptic.

It now appears preferable to substitute for (2) the equation of radial forces parallel to the plane of the ecliptic, which may be called (2*), and which is easily found to be the following:—

$$\frac{1}{2}\cdot\frac{d^2}{dt^2}\left\{\frac{a'}{a}\cdot\frac{r'}{a'}\cos 1'\right)^2\Big\} - \left(\frac{d}{dt}\left(\frac{a'}{a}\cdot\frac{r'}{a'}\cos 1'\right)\right)^2 - \left(\frac{a'}{a}\cdot\frac{r'}{a'}\cos 1'\right)^2\cdot\left(\frac{dv'}{dt}\right)^2 + \left(\frac{a'}{a}\right)^2\cdot\frac{\epsilon'+\mu'}{a'^3}\cdot\frac{a'}{r'}\cos^2 1'$$

$$= +\frac{P}{a}\cdot\frac{a'}{a}\cdot\frac{r'}{a'}\cdot\cos 1'.$$

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and the right-hand side of equation (2*) appears to consist of the following terms:—

$$+\left(e-\frac{eq.\,c.\,f.}{2\,grav.}\right)\cdot\left(\frac{c}{a}\right)^3\cdot\left(\frac{a}{a'}\right)^3\cdot\left(\frac{a'}{r'}\right)^3$$

$$\times\left\{\begin{array}{l}5\,(\sin\omega\,.\cos^2 l'.\sin v'+\cos\omega\,.\sin l'.\cos l')^2\\-2\,(\sin\omega\,.\cos^2 l'.\sin v'+\cos\omega\,.\sin l'.\cos l')\sin\omega\,.\sin v'\\-\cos^2 l'\end{array}\right\}$$

$$+\frac{\sigma'}{A'^2}\cdot\left(\frac{A'}{R'}\right)^3\cdot\left(\frac{a'}{a}\right)^2\cdot\left(\frac{r'}{a'}\right)^2\times\left\{3\cos^2 l'.\cos^2\overline{|v'-V'|}-\cos^2 l'\right\}$$

$$+\frac{\sigma'}{A'^2}\cdot\frac{\epsilon-\mu}{\epsilon+\mu}\cdot\frac{a}{A'}\cdot\left(\frac{A'}{R'}\right)^4\cdot\left(\frac{a'}{a}\right)^3\cdot\left(\frac{r'}{a'}\right)^3$$

$$\times\left\{-15\cos^3 l'.\cos^3\overline{|v-V|}+\frac{3}{2}\cos l'.\cos\overline{|v'-V'|}+3\cos^3 l'.\cos\overline{|v'-V'|}\right\}$$

$$+\frac{\sigma'}{A'^2}\cdot\frac{\epsilon^2+\mu^2}{(\epsilon+\mu)^2}\cdot\left(\frac{a}{A'}\right)^2\cdot\left(\frac{A'}{R'}\right)^5\cdot\left(\frac{a'}{a}\right)^4\cdot\left(\frac{r'}{a'}\right)^4$$

$$\times\left\{+\frac{35}{2}\cos^4 l'.\cos^4\overline{|v'-V'|}-\frac{15}{2}\cos^2 l'.\cos^2\overline{|v'-V'}-\frac{15}{2}\cos^4 l'.\cos^2\overline{|v'-V'|}+\frac{3}{2}\cos^2 l'\right\}$$

$$+\frac{\sigma'}{A'^2}\cdot\left(\frac{A'}{R'}\right)^3\cdot\left(\frac{r'}{a'}\right)^2\cdot\cos l'.\sin l'\times bt\times 3\,.\cos\overline{|v'-V'|}\,.\sin\overline{|V'-K|}$$

$$+\frac{\sigma'}{A'^2}\cdot\frac{\epsilon-\mu}{\epsilon+\mu}\cdot\frac{a'}{A'}\cdot\left(\frac{A'}{R'}\right)^4\cdot\left(\frac{r'}{a'}\right)^3.\cos^2 l'.\sin l'\times bt$$

$$\times\left\{-15\,.\cos^2\overline{|v'-V'|}\,.\sin\overline{|V'-K|}+3\sin\overline{|V'-K|}\right\};$$

and there are no terms multiplied by $\frac{dv}{dt}$.

1877, *March* 5.

The Astronomer Royal, in an oral address, adverted to M. Le Verrier's investigations on the possibility of discovery of an intra-mercurial planet, and to his issue of a circular requesting that observations of the Sun's disk for the passage of such planet might be made on March 21, more particularly on March 22, and on March 23. He pointed out that for observation of a transit whose time could not be even approximately predicted, but which certainly would occupy only two or three

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hours, it was necessary that observations should be made at widely separated meridians of the earth; and he stated that, at his instance, telegrams had been issued to one station in India, to three in Australia, to two in New Zealand, to Washington, U.S., and also (though it was doubtful whether it could arrive in time) to Santiago di Chili. It was much to be wished that observations could be obtained from San Francisco. He did not doubt that M. Struve would obtain observations in Eastern Siberia, and probably in Japan, and other islands. The Astronomer Royal also remarked that in scrutinizing the Sun's disk with a telescope, it might be possible to pass over some points without observation; and that in this instance photographic pictures, admitting of subsequent long and continuous study, would be preferable to eyeviews in a telescope, in which the power of deciding on the visibility of a spot must terminate with the actual view.

The Astronomer Royal also invited attention to the observations in connection with the determination of the Sun's parallax, which might advantageously be made at the approaching opposition of *Mars*. He cited from the *Monthly Notices* of 1857, his paper "On the means available for correcting our measures of the Sun's distance during the next 25 years," in which, alluding to the method by observing the displacement of *Mars* in right ascension when he is far east and far west of the meridian, and pointing out its facilities, he had concluded that "this method is the best of all." He had endeavoured, in several late Nos. of the *Monthly Notices*, to give facilities for the prosecution of this method, by observations, with an equatoreal, of the transits of *Mars* and stars; but an unexpected opportunity of obtaining observations, probably of a much superior class, has presented itself. Lord Lindsay is willing to lend his heliometer; and Mr. Gill, who has had extensive experience in the use of that instrument, and is perfectly acquainted with its adjustments of all kinds, offers his own time and labour at St. Helena, or Ascension. He proposes to undertake these observations on a guarantee of 500*l.* for expenses; any amount exceeding that sum to be borne by himself. This expense is a trifle compared with that which has been incurred for the transit of *Venus*, which, including the expenses of different nations, may amount to 200,000*l.* The Astronomer Royal suggested that this is an occasion on which the Royal Astronomical Society may well step in with its funds. He mentioned its funds in contradistinction to those of the Government, because the Government has been very liberal, and has felt a great strain put upon it by the expenses in observation of eclipses, and for the transit of *Venus*; and for that very reason the Astronomer Royal is very cautious indeed in suggesting any further application. If the Royal Astronomical Society will not support it from its funds, the Astronomer Royal hopes that the sum may be raised by contributions of individuals, in which he is willing to bear a part [naming a sum].

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On the Lunar Perturbations arising from the Planet Jupiter.

By E. Neison.

Shortly after the appearance of Professor Newcomb's paper "On a hitherto unnoticed Inequality in the Longitude of the Moon" (*Monthly Notices*, June 1876, p. 358), my attention was directed to a new term in the lunar longitude arising from the perturbing action of *Jupiter*, and having the value

$$-1''.0 \sin \{(2-2m_1-c)\,nt+f-2f_1+A\}.$$

where $(nt+f)$ is the Moon's mean longitude; $(cnt+f-A)$ the Moon's mean anomaly; and $(m_1 nt+f_1)$ the mean longitude of *Jupiter*. This term agreed well in period with the inequality discovered by Professor Newcomb, and its coefficient was only a little smaller, but was stated to be merely approximate. Being at the time engaged in a similar branch of the lunar theory, I was led to examine this new term and to determine its value with some accuracy.

This term arises from a portion of the disturbing function of the Moon due to the planets, which has not been examined by Laplace, Plana, or Pontécoulant, nor apparently by Hansen, namely, that portion depending on the difference in longitude of the Moon and planet. It is in form analogous to the *evection*, and obtains its sensible value from the approach to equality between the periods of the revolution of the Moon's perigee and of the orbital revolution of the planet *Jupiter*. This fact at once directed my attention to the associated inequality of long period whose argument is—

$$\{(2-2m_1-2c)\,nt-2f_1+2A\},$$

the value of which is still more dependent on the periods of the revolution of the Moon's perigee and the orbital revolution of the disturbing body.

In the ordinary lunar perturbations arising from the disturbing action of the Sun, the value of the inequality of long period is less than one-twentieth of the associated inequality of short period, because the period of the revolution of the Moon's perigee is nine times as great as the period of the apparent motion of the Sun. In the perturbations due to the disturbing action of the planet *Jupiter*, as the period of the revolution of the Moon's perigee is nearly four-fifths of the period of the revolution of the planet in its orbit, from the much closer approach to equality between the two periods, it is very probable that the inequality of long period would be almost as great as the associated inequality of short period.

The determination of the accurate values of these two terms with algebraical coefficients was found to be a work of unexpected difficulty and much labour. These and similar terms due to *Jupiter* rise by two orders on integration. As the ordinary

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lunar perturbations only converge by the same amount for each power of the disturbing force of the Sun, it is necessary to take into consideration the fourth power of the disturbing force of the Sun together with the first power of the disturbing force of *Jupiter*. After satisfying myself that both inequalities possessed a sensible value in comparison with the other inequalities arising from the action of the planets, the task of completely determining the value of these terms was postponed until the completion of my new Tables of the general development of the higher powers of the disturbing forces in the lunar theory.

These Tables have been now finished sufficiently to enable them being used to compute the value of these two inequalities, a work now of comparatively small trouble and difficulty; and the algebraical coefficients obtained, which are lengthy, have been reduced to numbers. The results are—

$$\delta r = -0''{\cdot}493 \cos\{(2-2m_1-c)nt+f-2f_1+A\} + 0''{\cdot}001 \cos\{(2-2m_1-2c)nt-2f_1+2A\}.$$

$$\delta v = -0''{\cdot}990 \sin\{(2-2m_1-c)nt+f-2f_1+A\} + 1''{\cdot}513 \sin\{(2-2m_1-2c)nt-2f_1+2A\}.$$

It is of course only in the longitude that these terms could become sensible. The labour in properly computing the value of these terms is shown by the fact that it cannot properly be done unless over twenty similar terms have had their values previously ascertained.

These two new terms derive additional interest from the fact that they are the first terms derived from the second portion of the disturbing force of the planets which have been found to possess sensible coefficients. They, moreover, have considerably larger values than any other inequalities due to *Jupiter*.

Corrections to the Nautical Almanac Places of the Moon for Longitude Observations in connection with the Transit of Venus 1874. By Captain G. L. Tupman.

(*Communicated by the Astronomer Royal.*)

These corrections have been deduced entirely from observations at places which have been connected by galvanic signals with the Royal Observatory, Greenwich, for longitude, and where both limbs of the Moon were equally observed, viz.:—

1° of both elements at Greenwich, with the Transit-Circle and Altazimuth, between 1874, Sept. 15, and 1875, Feb. 23.

2° of both elements at Paris, between 1874, Sept. 14, and 1875, Feb. 22, including those made with the Gambey instruments, published in *Comptes Rendus* 1875, May 24.

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3° of Right Ascension at Königsberg between 1874, Sept. 19, and 1875, Feb. 26, published in the *Astronomische Nachrichten*, Nos. 2020 and 2050.

4° of Right Ascension at Strasburg between 1874, Oct. 23, and 1875, Feb. 25, *Astronomische Nachrichten*, No. 2050.

5° of North Polar Distance at the Radcliffe Observatory, Oxford, between 1874, Sept. 18, and 1875, Jan. 21.†

The published errors of the tabular R.A. at Königsberg differ considerably from the errors obtained at the other observatories, and the discordance appears to vary with the Moon's declination, as if the instrumental corrections were imperfect. As, however, the observed R.A.s of the stars observed near the Moon are also given, new errors of the tabular R.A. were determined in the following manner:—

The apparent R.A. of every star at transit over the Meridian of Königsberg, founded on a mean R.A. derived from the Greenwich Catalogue for 1864, or, in default, 1860, was computed and compared with the observed R.A. A correction for the day was thus obtained from each star, and the mean from all the stars was applied to the observed R.A. of the Moon's limb.

The tabular R.A. of the limb was then interpolated with fourth differences from the section "Moon culminating Stars" in the *Nautical Almanac*, adopting for the longitude of Königsberg Observatory $1^h\ 21^m\ 59^s{\cdot}32$, which results from galvanic signals, viz.:—

	m	s	
Brussels east of Greenwich	17	28·90	(*Royal Obs. MSS.*)
Berlin east of Brussels	36	6·42	(*Astr. Nach.* XLV. 225).
Königsberg east of Berlin	28	24·00	(*Astr. Nach.* LVII. 350).

The difference between the interpolated R.A. and the observed R.A. corrected as described above was taken as the error of the tables.

A similar comparison of the observed and tabular R.A. of stars observed near the Moon at Strasburg showed no systematic discordances; the published corrections were therefore adopted, as were also the Paris corrections.

The mean correction for each day, allowing half weight to the Greenwich Altazimuth and the Königsberg observations, was then plotted off on charts of ruled squares, treating the R.A. and N.P.D. separately, and a free curve drawn through all the points. The adopted position of this curve among the points was submitted to several persons for criticism, and is believed to give the corrections as accurately as the observations admit.

Professor Newcomb's corrections were then plotted off on the same charts, and as the "observation-curve" was weak at the beginning and end of each lunation, it was made parallel to Professor Newcomb's.

The corrections taken from this modified portion of the curve are denoted by an asterisk (*).

† The Washington Observations had not been received at Greenwich when the corrections were determined; they would have been a valuable addition.

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Corrections of the Moon's Tabular Place in the Nautical Almanac.

Day of the Month.	1874 September. R.A. s	N.P.D. "	October. R.A. s	N.P.D. "	November. R.A. s	N.P.D. "	December. R.A. s	N.P.D. "	1875 January. R.A. s	N.P.D. "	February. R.A. s	N.P.D. "
7											−·30	+3·5
8											−·30	+4·2
9											−·31	+4·5
10									−·40*	0·0	−·35	+4·8
11									−·42*	+1·3	−·37	+4·8
12					−·43*	+2·0	−·34*	+2·0	−·44*	+2·5	−·41	+4·5
13	−·37		−·27*	−3·0	−·42*	+2·7	−·35*	+3·0	−·45*	+3·4	−·45	+3·5
14	−·38	−1·0	−·28*	−2·5	−·40*	+3·1	−·36*	+3·8	−·47	+3·8	−·50	+2·3
15	−·40	−0·3	−·30	−2·0	−·37*	+3·4	−·38*	+4·5	−·48	+4·0	−·55	+1·0
16	−·41	0·0	−·35	−1·3	−·35	+3·6	−·40	+5·0	−·50	+3·6	−·57	−0·6
17	−·42	+0·6	−·38	−0·4	−·32	+3·6	−·45	+5·0	−·52	+2·7	−·60	−2·6
18	−·43	+1·3	−·41	+0·7	−·35	+3·6	−·48	+4·5	−·54	+1·4	−·58	−3·6
19	−·44	+1·7	−·44	+2·0	−·37	+3·5	−·51	+3·4	−·56	−0·6	−·55	−4·2
20	−·45	+2·3	−·46	+3·5	−·44	+3·5	−·55	+1·7	−·59	−2·1	−·53	−4·2
21	−·47	+2·8	−·50	+5·0	−·51	+3·3	−·59	0·0	−·62	−3·2	−·48	−3·8
22	−·49	+3·5	−·54	+5·7	−·59	+3·0	−·64	−1·5	−·65	−3·5	−·44	−3·2
23	−·52	+4·1	−·58	+6·0	−·67	+2·6	−·69	−3·0	−·66	−3·6	−·41	−2·0
24	−·56	+5·0	−·65	+5·7	−·75	+2·0	−·74	−4·4	−·66	−3·5	−·39	

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Day of the Month.	1874 September. R.A. s	N.P.D. "	October. R.A. s	N.P.D. "	November. R.A. s	N.P.D. "	December. R.A. s	N.P.D. "	1875 January. R.A. s	N.P.D. "	February. R.A. s	N.P.D. "
25	−·61	+5·8	−·75	+5·2	−·85	+1·2	−·75*	−5·3	−·65	−3·3	−·36	
26	−·69	+6·2	−·80	+4·1	−·92	0·0	−·76*	−6·1	−·62	−3·0	−·35	
27	−·77	+5·7	−·80	−2·8	−·91	−1·0	−·73*	−6·7	−·57	−2·6	−·35	
28	−·83	+4·9	−·78	−1·3	−·80	−1·6	−·66*	−7·1	−·53	−2·2		
29	−·83	+4·0	−·76	−0·4	−·66	−2·3	−·60*	−7·1	−·47	−1·7		
30	−·80	+3·0	−·74	−1·6	−·60	−2·8	−·55*	−7·0	−·42	−1·4		
31			−·70	−2·6			−·51*	−6·6	−·40*	−1·0		

	October.		November.		December.		January.		February.	
1	−·75	+1·7	−·66	−3·5	−·55	−3·0	−·48*	−6·0	−·38*	−0·5
2	−·70	+0·6	−·63	−4·1	−·52	−3·1	−·45*	−5·3	−·36*	0·0
3	−·66	−0·7	−·59	−4·4	−·51	−3·0	−·43*	−4·4	−·36*	+0·5
4	−·63	−2·1	−·55	−4·5	−·50	−2·8	−·40*		−·36*	+1·0
5	−·59	−3·2	−·52*	−4·3	−·50*	−2·5				
6	−·56	−3·6	−·48*	−4·0	−·50*	−2·0				
7	−·53*	−4·0								
8	−·51*	−4·0								

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The differences between the individual observations and the curve are shown below, the sign + signifying that the observed R.A. and N.P.D. are greater than the adopted.

	Right Ascension.					North Polar Distance.			
1874	Greenwich Transit Circle. s	Greenwich Altazimuth. s	Paris. s	Königsberg. s	Strasburg. s	Greenwich Transit Circle. "	Greenwich Altazimuth. "	Paris. "	Oxford. "
Sept. 14			−·08						
,, 15		+·30	−·11				−3·3		
,, 18		+·40	−·18				+1·5	−2·1	+1·8
,, 19		+·35	(+·05 / −·19)	−·08			0·0	+4·2	
,, 20				−·06					
,, 21	+·03	+·19		+·01		−0·2	+0·7	−3·8	+1·5
,, 22	+·02	+·18		−·07		−0·6	−3·0		+2·0
,, 23		−·15		−·10			−1·9		−0·6
,, 24		−·02	−·14				+2·1	−2·0	
,, 25	−·02	+·20	+·06			−1·0	+4·4	−1·3	+0·2
,, 26	+·07	·00	+·05	−·11		−0·9	+0·2	+1·0	
,, 27	+·11	−·34				−0·9	+1·3		
,, 28	+·17	−·30				−1·5	+0·5		
,, 29		−·04		+·04			−0·8		
Oct. 1		−·25					+1·9		
,, 2		−·07					+2·0		
,, 3		+·28					−2·1		

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1874	Right Ascension.					North Polar Distance.			
	Greenwich Transit Circle.	Greenwich Altazimuth.	Paris.	Königsberg	Strasburg.	Greenwich Transit Circle.	Greenwich Altazimuth.	Paris.	Oxford.
	s	s	s	s	s	"	"	"	"
Oct. 4		+·01					+1·3		
„ 5		−·53	+·23				−0·9	+0·5	
„ 14			+·04						
„ 15			−·11						
„ 16				+·07					
„ 18	+·11	−·16				+0·8	−1·7		
„ 19	+·06	−·26				+1·5	+1·3		
„ 20	+·02	−·01	−·02			−1·7	−0·4	−3·4	
„ 21	+·12	+·12				+1·5	+3·7		+2·8
„ 22	−·01	−·14				+0·2	−2·1		
„ 23		−·24	(·00 / −·09)		−·06		−2·4	−0·5	
„ 24		+·17	(+·04 / −·14)	−·16	−·11		+0·4	(−1·4 / +2·6)	
„ 25		−·26		−·07	−·24		−2·3	+4·2	
„ 26			+·01					+2·5	
„ 27	+·23	−·20	−·20		−·03	−1·0	−1·1	+2·1	
„ 28	+·05	−·06				−1·5	−0·9		
„ 29				·00					
„ 30		−·24		+·19			−2·4		

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Oct.	31		−·37					−1·6		
Nov.	1			+·29					+1·1	
,,	2		+·17					−0·1		
,,	3		−·22	−·15				+0·7	−1·3	
,,	4		−·28					+0·9		
,,	13		−·02					−3·1		
,,	14			−·14	+·21				+1·2	+2·1
,,	15					+·14				
,,	17	+·11	−·21	−·05			+1·0	−4·0		
,,	18		−·11					−6·0		
,,	19	+·12	+·14	−·18			+1·2	+3·1	−0·9	−3·4
,,	20	+·07	−·18				−2·4	−1·1		
,,	21			(+·22 −·22)		+·13			(+2·1 −1·1)	
,,	22	−·16	+·14			−·08	+0·8	+2·0		
,,	23		−·16	(−·02 −·17)				+1·9	(−3·1 +1·8)	−2·6
,,	24		+·23	+·04		−·07		+5·1		
,,	25			−·11					+0·3	
,,	26	−·07				+·10	−5·9			
,,	27		+·01					+1·2		
,,	29		−·01					+0·3		
Dec.	1	−·01	−·18				+1·4	−0·5		

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	Right Ascension.					North Polar Distance.			
	Greenwich Transit Circle.	Greenwich Altazimuth.	Paris.	Königsberg.	Strasburg.	Greenwich Transit Circle.	Greenwich Altazimuth.	Paris.	Oxford.
1874	s	s	s	s	s	"	"	"	"
Dec. 2	+·19	·00	−·02		+·06	−1·6	+2·5		
,, 3		−·20	+·07		−·05		−0·2	−0·6	
,, 14		+·36					−2·1		+0·7
,, 15			−·11						
,, 16		−·09					−0·4		+0·6
,, 17	+·07	−·08				−1·3	+2·6		
,, 18		+·09					+0·4		
,, 19	+·01	−·18				−0·4	−0·5		+2·0
,, 20		+·04					−2·5		
,, 21	·00					+1·3	−2·8		+1·1
,, 23		·00					+0·8		
,, 25	+·03					−0·5			
,, 27		−·26					+1·7		
,, 29	+·23	−·13				0·0	−1·5		
,, 31		−·21	−·16	−·11			−2·5	+1·3	
1875									
Jan. 1		+·13							
,, 13	−·05	+·26	−·17	+·17		−1·1	−0·4	+0·3	−3·9
,, 14				+·12					
,, 15	+·06	−·28				+0·1	+0·2		−0·6

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Jan.	16		−·05					+1·5		−1·5
„	17		−·34					0·0		
„	18	+·05	+·22				−1·6	+1·2		−6·4
„	19		−·14	(+·04 −·09)				+0·7	(+1·3 +2·5)	
„	20	+·28	+·06	(+·04 −·11)			−1·6	+1·6	(−3·8 0·0)	−4·3
„	21		−·02				−1·6	+1·4		−3·2
„	22		+·14			−·09		+3·3		
„	24		+·33					−0·5		
„	25		−·30			+·07		+0·6		
„	26					+·04				
„	27					−·30				
„	28				−·17					
„	29		+·10					0·0		
„	30		+·03	−·10	−·25	+·13	−0·5	+1·5		
„	31		−·20	+·14				−0·6		
Feb.	1		+·19					−6·5		
„	8			−·09						
„	10					+·37				
„	11			−·02	−·18					
„	12		−·07							
„	13				−·03					

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1875	Right Ascension. Greenwich Transit Circle. s	Greenwich Altazimuth. s	Paris. s	Königsberg. s	Strasburg. s	North Polar Distance. Greenwich Transit Circle. "	Greenwich Altazimuth. "	Paris. "	Oxford.
,, 14		−·02					−3·1		
,, 15	+·15	−·24	(+·03 / −·10)	+·08		−0·3	+4·0	(−1·8 / +1·2)	
,, 16		+·30		−·02			−2·4		
,, 17		−·12					+1·2		
,, 18	+·08	+·13	(+·21 / −·18)			−1·6	+1·6	(−0·3 / +0·2)	
,, 19			(−·01 / −·05)	+·11				(−0·8 / −0·1)	
,, 21	+·12	−·16			+·04	+1·0	−0·5		
,, 22	+·09	−·16	−·15		·00	−1·1	−2·4	+0·1	
,, 23		−·25		−·20	+·23		+3·0		
,, 24				−·12	+·24				
,, 25				−·15	+·07				
,, 26				+·04					

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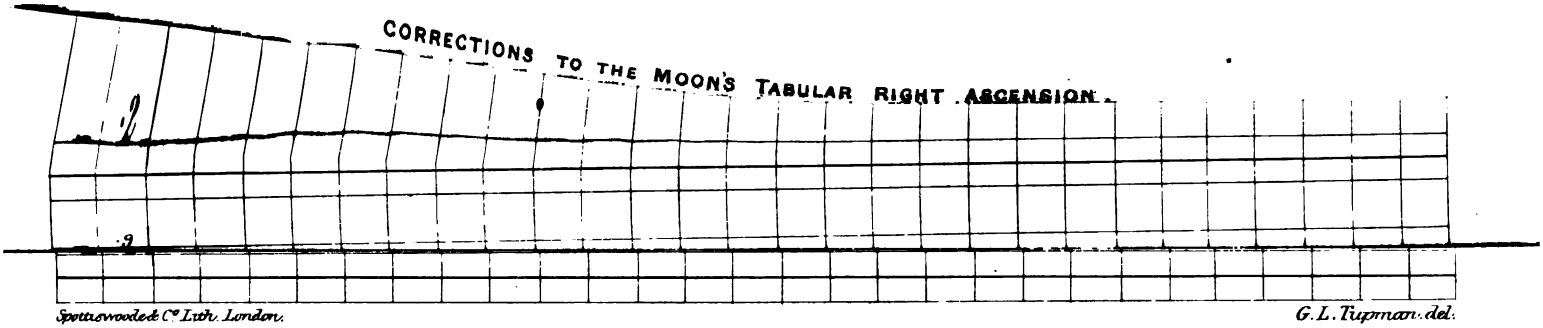

EXPLANATION OF THE ENGRAVED CURVES.

The dots represent the actual observations as weighted in the following manner:–

The observations with the Greenwich Transit Circle, at Paris, and at Strasburg, have the weight 2; those at Königsberg and with the Greenwich Altazimuth the weight 1.

The number of dots shows the weight for the day; the centre dot of each group should be on the ordinate representing the day.

The strong black line is the adopted correction; the fine line shows the correction deduced by Professor Newcomb.

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On the Visibility of the Unilluminated Portion of the Disk of Venus. By Señor A. T. Arcimis.

I had only one favourable opportunity of observing this phenomenon in the afternoon of June 19, 1876; on the previous and following days the sky was overcast towards the West, and the prevailing high wind caused considerable vibration of the telescope.

At $7^h\ 15^m$ the Sun being slightly obscured by clouds, I could see the planet with the naked eye; the finder enabled me to distinguish perfectly the shape and direction of the crescent. It presented, when viewed through the telescope provided with an eye-piece of 92 diameters, a most beautiful aspect, although it was very difficult to focus, and the image almost invariably was irisated. The concave portion appeared as a broken or undulating line, somewhat similar to the Moon's, and no illuminated or bright cusps were visible on the dark portion.

The two horns were easily distinguishable. They were unequal, the northern being the sharpest. Close to the southern extremity an excavation or indentation of an almost black colour was perceptible. I could not discard the idea that the body under observation was a partially illuminated sphere; and this appearance became more marked when I employed a very faint red modifier. The phenomenon of irradiation seemed to me more striking than the Moon's; that is to say, the bright portion appeared very considerably larger than the dark one.

I had considerable difficulty in perceiving the secondary light, but I succeeded in doing so by employing the well-known device of not sighting it directly, so that the light might impinge on a more impressionable point of the retina. Its colour, to my sight, was greyish, or somewhat violaceous, and extremely faint. It will be well to bear in mind that this colour might be due to a deficient achromatic condition of the telescope.

At $7^h\ 30^m$ both horns appeared to be equal, and from that moment the sky was overcast, and I have since had no further opportunity of observing the planet.

Cadiz,
1876, *December* 30.

Phenomena of Jupiter's Satellites observed at Cadiz. By Señor A. T. Arcimis.

The observations were made with a 4-inch Secretan Refractor and a 92-power eye-piece. The hour of the clock was determined by equal altitudes of the Sun or stars, taken with the sextant and the artificial horizon. The ephemerides are from the *Nautical Almanac* of San Fernando Observatory; the geographical co-ordinates of my Observatory are:—

Lat. N. $= 36°\ 31'\ 52''.8$

Long. W. Greenwich $= 0^h\ 25^m\ 11^s.7$

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Date of Observation.	Satellite.	Phase.	Mean Solar Time of Observation.	Mean Solar Time from N.A.	Diff.	Remarks.
1876.			h m s	h m s	m s	
April 24	I	D	8 9 4	8 9 2	−0 2	Moon absent; clear sky.
„ 25	II	D	14 43 39	14 43 40	+0 1	do. do.
„ 26	III	D	11 16 55	11 16 52	−0 3	Good observation.
„ 26	III	R	12 58 43	12 58 35	−0 8	do.
May 1	I	D	10 2 53	10 2 51	−0 2	do.
„ 3	III	D	15 15 1	15 14 53	−0 8	Bad definition.
„ 8	I	D	11 56 12	11 56 44	−0 32	Clear sky; Moon bright near planet; satellite very tremulous; I lost it sometimes.
„ 20	II	R	14 16 30	14 16 26	−0 4	Good observation.
„ 24	I	R	12 21 7	12 21 1	−0 6	do.
June 1	III	R	8 51 3	8 51 12	+0 9	Bright Moon.
„ 7	II	R	8 47 40	8 46 46	−0 54	Bright Moon; clear sky.
„ 8	III	D	11 7 28	11 5 40	−1 48	Good observation.
„ 8	III	R	12 48 17	12 50 3	+1 46	do.
„ 9	I	R	10 38 19	10 38 5	−0 14	Good obs.; clear sky.
„ 16	I	R	12 32 21	12 32 28	+0 7	do.
„ 25	I	R	8 57 29	8 55 33	−1 56	Bad obs.; strong wind.
July 2	I	R	10 50 23	10 50 6	−0 17	Good obs.; planet near Moon.
„ 14	III	D	not obs.	6 59 33		
„ 14	III	R	8 49 33	8 46 57	−2 36	Strong wind; telescope vibrates.
„ 16	I	R	14 37 48	14 39 23	+1 35	do do.
„ 16	II	R	11 11 52	11 9 35	−2 17	do. do.
„ 18	I	R	9 14 24	9 8 5	−6 19	Clear sky.
„ 25	I	R	11 1 6	11 2 48	+1 42	Cloudy; planet near horizon.
Aug. 10	II	R	8 23 0	8 21 48	−1 12	Very strong wind; bad observation.
„ 10	I	R	9 21 17	9 20 58	−0 19	do. do.
„ 26	I	R	7 39 16	7 39 11	−0 5	Good observ.; Moon present.
„ 26	III	D	6 53 59	6 53 21	−0 38	Good obs.; twilight.
„ 26	III	R	8 45 42	8 45 9	−0 33	Good observ.; Moon present.

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Observations of Occultations of Stars by the Moon, made at Cadiz in the year 1876. By Señor A. T. Arcimis.

Date of Observation. 1876	Stars.	Mag.	Phase.	Mean Solar Time of Observation. h m s	Mean Solar Time from *N.A.* h m s	Diff. m s	Remarks.
May 27	γ Cancri	4	D	8 45 47	8 45 38	−0 9	Dark limb.
„ 27	γ Cancri	4	R	9 42 5	9 41 38	−0 27	
Aug. 28	C.A.B. 6107	4	D	9 26 7	9 26 38	+0 31	
„ 28	C,A.B. 6107	4	R	10 20 15	10 19 38	+0 23	Clear sky; dark limb; Moon in □.
Sept. 29	ι Aquarii	4	D	13 54 3	13 53 38	−0 25	Good observation.
„ 29	ι Aquarii	4	R	14 22 17	14 26 38	+4 21	Moon near horizon.
Oct. 6	17 Tauri	4	D	7 57 2	7 56 38	−0 24	Bright limb.
„ 6	17 Tauri	4	R	8 44 10	8 45 38	+1 28	Dark limb.
„ 6	20 Tauri	5	D	8 39 41	8 35 38	−4 3	Bright limb; vapours.
„ 6	20 Tauri	5	R	9 7 23	9 5 38	−1 45	Dark limb; good observation.
„ 6	23 Tauri	5	D	8 25 4	8 27 38	+2 34	Bright limb; bad observation.
„ 6	23 Tauri	5	R	9 2 51	9 1 38	−1 13	Dark limb; bad observation.
„ 6	η Tauri	3	D	8 53 32	8 53 38	+0 6	Bright limb; bad observation.
„ 6	η Tauri	3	R	9 38 9	9 37 38	−0 31	Dark limb; good observation.
„ 26	δ Capricorni	3	D	12 0 33	12 1 38	+1 5	Dark limb; good obs.; Moon near horizon.

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The Occultation of Regulus, February 26, 1877.

By F. C. Penrose, Esq.

The occultation of Regulus, Feb. 26, 1877, was observed here.

	h	m	s	
Disappearance	12	46	14·8	G.M.T.
Reappearance	13	51	5·6	

Two observers watched for the disappearance; one with a 2¼-inch O. G., the other with a 5¼-inch O. G. The clouds were sufficiently dense to obscure the star in the 2¼-inch before the occultation, but it was distinctly seen in the 5¼-inch on the dark limb. At the reappearance the sky was perfectly clear, and the star was seen as a bright indent upon the limb of the Moon.

Colebyfield, Wimbledon.

Latitude 51° 24′ 58″.

Longitude $0^h\ 0^m\ 55^s{\cdot}15$.

Total Eclipse of the Moon, February 27, 1877.

By F. C. Penrose, Esq.

I offer a drawing made of the Total Eclipse of the Moon on the 27th ulto., at the phase of reappearance of the sunlight. It could not have failed to be remarked during totality, how very much brighter the northern and southern parts of the Moon's limb were than the eastern and western parts; presumably arising from some interference with the light refracted through the Earth's atmosphere, from a greater prevalence of clouds in the equatoreal regions than at the two poles. Some amount of *specular* reflection, at very flat angles, from the northern and southern ice, may have also aided in producing this effect.

With respect to the general phenomenon of the total lunar eclipse, I would observe that, although no value appears in works on Navigation to be placed on this phenomenon for the determination of longitude at sea, although I admit that this would be perfectly reasonable in the case of a partial eclipse; yet, when the eclipse is total, it seems quite capable of giving a useful result. The two phases of the beginning and end of totality should be observed when practicable, and the mean taken. By combining these observations in the total lunar eclipse of July 12, 1870, I obtained a G.M.T. differing from the prediction in the *Nautical Almanac* by 39ˢ, and from the eclipse of last February by 29ˢ, both being later than the prediction. There would be less difference than might be supposed in the use of smaller telescopes; for I found that simultaneous unaided eye observations of both phases made on the last occasion did not differ by many seconds. This could, after a little study, be allowed for; and probably, as far as the observation is concerned, the error need not exceed 15 or 20 seconds. The errors of the tables

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would of course be shared by this with any other lunar method. The times I noted were,

	h	m	s	
Totality commenced	6	28	13	G.M.T.
Totality ended	8	3	15	

The colour seen upon the Moon on this occasion, and especially the remarkable bluish hue which spread over the lunar regions preceding the reappearance of the sunlight, could not fail strongly to impress upon the mind the wish to realise in imagination the effect that would be seen from the Moon of the prismatic colours surrounding our planet, with the Sun's corona in the background and with *Venus* not far distant.

Total Eclipse of the Moon, February 27, 1877.

By the Rev. S. J. Perry.

The night was cloudless, but there was a sharp frost, which made the air unsteady. The Moon rose partially eclipsed. Using a power of about 100 with an 8-inch achromatic, the following contacts were observed :—

	h	m	s	
Commencement of Totality	6	27	24·5	G.M.T.
End of Totality	8	4	8·5	
Last contact with Shadow	9	0	6·0	

The time was taken with a Frodsham chronometer, compared during the eclipse with the standard sidereal clock; and clock stars were observed.

The darkness of that portion of the penumbra which was in close proximity to the umbra was so great, that the last contact was difficult to observe.

Several reappearances of occulted stars were seen during totality, and might have been well observed.

The thin circle of light on the Moon's limb was in such striking contrast with the cloudy dull brick-red shading of the centre, that to many persons it seemed as if the Moon was not completely immersed in the Earth's shadow.

Stonyhurst Observatory,
1877, *February* 28.

On Kepler's Problem. By M. A. de Gasparis.

(*Translation.*)

The numerical solution of the equation $M = E - e'' \sin E$ may be useful, especially for the new planets, for comets of elliptic orbit, and for the satellites of double stars, the number of which

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is always increasing. I here reproduce a solution, very much simplified, which, proceeding by direct operations, gives to within a few seconds the value of E.

I assume $E = M + n.10°$, and we then have by substitution

$$n\frac{(10°)''}{R''} = e \sin (M + n.10°), \quad \ldots\ldots\ldots \quad (1)$$

or, if we please,

$$10n\frac{(1°)''}{R''} = e \sin (M + 10n.1°) \quad \ldots\ldots\ldots \quad (2)$$

The unknown quantity is here n, and we know that its integer part is less than 6. For a first step I employ logarithms to three places of decimals, for the second step to five places. Moreover $\log \frac{(10°)''}{R''} = 9{\cdot}2418774$, and therefore $\log \frac{(1°)''}{R''} = 8{\cdot}2418774$ This being so,

1° I write in a line the logarithms of 1, 2, 3, 4, 5, 6.

2° Below these the logarithm of $\frac{(10°)''}{R''}$, and I take the sums.

This operation is common to all the examples which present themselves.

3° On another line, respectively below the preceding numbers, I write (six times) $\log e$.

4° Below the $\log e$'s, I write the log sin $(M+1.10°)$, log sin $(M+2.10°)$... log sin $(M+6.10°)$; and I take the sums.

We have at sight the limits of the integer part of n, and the tenths are obtained by a simple proportion.

Suppose, for example, $M = 27°\ 15'\ 7''{\cdot}42$, $\log e = 9{\cdot}9231544$, we proceed as follows:—

	1	2	3	4	5	6
$\log n$	0·000	0·301	0·477	0·602	0·699	0·778
$\log \frac{(10°)''}{R''}$	9·242	9·242	9·242	9·242	9·242	9·242
	9·242	9·543	9·719	9·844	9·941	0·020
$\log e$	9·923	9·923	9·923	9·923	9·923	9·923
log sin $(M+n.10°)$	9·782	9·866	9·925	9·965	9·989	0·000
	9·705	9·789	9·848	9·888	9·912	9·923

Therefore n is between 4 and 5. The lower sum of the vertical line 4 is greater than the upper sum by 44; on the line 5 it is less by 29; therefore $n = 4 + \frac{44}{44+29} = 4{\cdot}6$. We have consequently

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$E = 27° 15' + 46° = 73° 15'$. Since $10n = 46$, I employ in the second case the equation (2) as follows:—

log 10*n*	1·65321	1·66276	1·67210
$\log \frac{(1°)''}{R''}$	8·24188	8·24188	8·24188
	9·89509	9·90464	9·91398
log *e*	9·92315	9·92315	9·92315
log sin (M + 10*n*.1°)	9·97882	9·98117	9·98338
	9·90197	9·90432	9·90653

Here $10n = 45 + \frac{688}{688+32} = 45·956$; but $45°·956 = 45° 57' 22''$.

Therefore $E = 27° 15' 7''·4 + 45° 57' 21''·6$; or, $E = 73° 12' 29''$, a value exact to within a few seconds.

The definitive correction ΔE, may be obtained from

$$\Delta E = \frac{M + e \sin E - E}{1 - e \cos E}.$$

Naples, Feb. 7, 1877.

Note on a Transformation of Lagrange's Equations of Motion in Generalised Coordinates, which is convenient in Physical Astronomy. By Robert S. Ball, LL.D., F.R.S., Royal Astronomer of Ireland.

I can hardly suppose that the following Note contains anything which has not already been published; but as I have not met with this transformation in my reading, nor conversed with anyone who is acquainted with it, I am led to believe that, even if it be not new, it is certainly not so well known as its convenience deserves.

Lagrange's Equations of Motion in Generalised Coordinates are not, in their usual form, particularly well adapted for Physical Astronomy. In a problem in Physical Astronomy, what we want to learn is the *relative* coordinates of a system, while its *absolute* situation in space does not concern us. Lagrange's equations, however, involve *both* the relative and the absolute coordinates, and we are obliged to remove the latter by elimination. It is the object of this Note to point out a very simple transformation of Lagrange's equations which obviates the inconvenience of having to perform the elimination. This advantage is gained without detracting from the simplicity and directness which render Lagrange's equations such exquisite instruments of analysis.

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If q be one of the generalised coordinates, and T and V be the kinetic and potential energies of the system, then Lagrange's equations have the form

$$\frac{d}{dt}\left(\frac{d\mathrm{T}}{d\dot{q}}\right)-\frac{d\mathrm{T}}{dq}=-\frac{d\mathrm{V}}{dq};$$

V depends solely upon the relative coordinates of the system. It is therefore only the function T which requires to be purged from the three objectionable quantities. This is effected by simply replacing T by a different function, which we shall denote by T′.

We proceed to show that this substitution is allowable, and that it answers the end for which it is intended.

Let p_1, p_2, p_3 be the rectangular coordinates of the centre of inertia P of one of the bodies with reference to axes fixed in space. Let the relative generalised coordinates of the system be $q_1, \ldots q_{n-3}$. When the last-mentioned coordinates and the corresponding generalised velocities are known, then everything is known about the system except its actual situation in space. What we want to obtain is a system of $n-3$ equations in $q_1, \ldots q_{n-3}$, from which p_1, p_2, p_3 are absent.

Let x_1, y_1, z_1 be the rectangular coordinates of the centre of inertia of one of the masses m_1 with respect to three rectangular axes through P parallel to the fixed axes, then we have

$$\mathrm{T}=\frac{1}{2}\Sigma m_1(\dot{p}_1+\dot{x}_1)^2+\frac{1}{2}\Sigma m_1(\dot{p}_2+\dot{y}_1)^2+\frac{1}{2}\Sigma m_1(\dot{p}_3+\dot{z}_1)^2+\mathrm{R}_0,$$

when R_0 is that function of $q_1, \ldots q_{n-3}$ and $\dot{q}_1, \ldots \dot{q}_{n-3}$ which expresses the kinetic energy of the rotations of the bodies of the system about their centres of inertia.

Then we have

$$\mathrm{T}=\frac{1}{2}(\dot{p}_1^2+\dot{p}_2^2+\dot{p}_3^2)\Sigma m_1+\dot{p}_1\Sigma m_1\dot{x}_1+\dot{p}_2\Sigma m_1\dot{y}_1+\dot{p}_3\Sigma m_1\dot{z}_1$$

$$+\frac{1}{2}(\dot{x}_1^2+\dot{y}_1^2+\dot{z}_1^2)\Sigma m_1+\mathrm{R}_0.$$

We first form the generalised equations of motion in Lagrange's form corresponding to the coordinate p_1:

$$\frac{d\mathrm{T}}{d\dot{p}_1}=\dot{p}_1\Sigma m_1+\Sigma m_1\dot{x}_1,$$

$$\frac{d\mathrm{T}}{dp_1}=0,$$

$$\frac{d\mathrm{V}}{dp_1}=0;$$

whence the equation of motion is

$$\frac{d}{dt}(\dot{p}_1\Sigma m_1+\Sigma m_1\dot{x}_1)=0,$$

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and two similar equations, corresponding to p_2 and p_3. If then u, v, w be constants with respect to the time,

$$\dot{p}_1 \Sigma m_1 + \Sigma m_1 \dot{x}_1 = u \Sigma m_1,$$

$$\dot{p}_2 \Sigma m_1 + \Sigma m_1 \dot{y}_1 = v \Sigma m_1,$$

$$\dot{p}_3 \Sigma m_1 + \Sigma m_1 \dot{z}_1 = w \Sigma m_1.$$

We now proceed to form the equations in $q_1, \ldots q_{n-3}$. We shall use the letter q as typical of the series.

If we make

$$T' = \frac{1}{2} (\dot{x}_1^2 + \dot{y}_1^2 + \dot{z}_1^2) \Sigma m_1$$

$$- \frac{1}{2 \Sigma m_1} \{(\Sigma m_1 \dot{x}_1)^2 + (\Sigma m_1 \dot{y}_1)^2 + (\Sigma m_1 \dot{z}_1)^2\} + R_0,$$

then it is easily verified that

$$T = \frac{1}{2} (u^2 + v^2 + w^2) \Sigma m_1 + T'.$$

Making this substitution in the equation of motion corresponding to q, viz.

$$\frac{d}{dt}\left(\frac{dT}{d\dot{q}}\right) - \frac{dT}{dq} = -\frac{dV}{dq},$$

the equation becomes

$$\left\{\frac{d}{dt}\left(\frac{du}{d\dot{q}}\right) - \frac{du}{dq}\right\} u \Sigma m' + \left\{\frac{d}{dt}\left(\frac{dv}{d\dot{q}}\right) - \frac{dv}{dq}\right\} v \Sigma m' + \left\{\frac{d}{dt}\left(\frac{dw}{d\dot{q}}\right) - \frac{dw}{dq}\right\} w \Sigma m'$$

$$+ \frac{d}{dt}\left(\frac{dT'}{d\dot{q}}\right) - \frac{dT'}{dq} = -\frac{dV}{dq}.$$

But this equation may be greatly simplified, for

$$u = \frac{d}{dt}\left(p_1 + \frac{\Sigma m_1 x_1}{\Sigma m_1}\right);$$

or, if we assume

$$U = \frac{\Sigma m_1 x_1}{\Sigma m_1},$$

we have

$$u = \dot{p}_1 + \frac{dU}{dt};$$

but U is a function of $q_1, \ldots q_{n-3}$, and does not contain t or $\dot{q}_1, \ldots \dot{q}_{n-3}$, or p_1, p_2, p_3, whence we may write

$$u = \dot{p}_1 + \Sigma \frac{dU}{dq} \dot{q}.$$

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It follows that

$$\frac{du}{d\dot{q}} = \frac{dU}{dq},$$

$$\frac{du}{dq} = \frac{d^2U}{dt\,dq};$$

and finally

$$\frac{d}{dt}\left(\frac{du}{d\dot{q}}\right) - \frac{du}{dq} = 0.$$

Similarly it may be shown that

$$\frac{d}{dt}\left(\frac{dv}{d\dot{q}}\right) - \frac{dv}{dq} = 0,$$

$$\frac{d}{dt}\left(\frac{dw}{d\dot{q}}\right) - \frac{dw}{dq} = 0;$$

and therefore the equation of motion reduces to

$$\frac{d}{dt}\left(\frac{dT'}{d\dot{q}}\right) - \frac{dT'}{dq} = -\frac{dV}{dq}.$$

By slightly altering the method of expressing the function T, the final result may be stated in the following theorem:—

Let V denote the potential energy of a system of attracting bodies.

Let T' denote the sum of the kinetic energies of the rotations of each body of the system about its centre of inertia added to

$$\Sigma \frac{m_1 m_2}{2\Sigma m_1} [1, 2],$$

where the symbol $[1, 2]$ denotes the square of the relative velocity of the centres of inertia of the masses m_1 and m_2, and the summation includes every pair of the bodies of the system.

Let $q_1, \ldots q_{n-3}$ be $n-3$ generalised coordinates adequate to specify everything about the position and aspect of the system at a given epoch, except its actual situation in space, then the $n-3$ equations which will determine the motion are

$$\frac{d}{dt}\left(\frac{dT'}{d\dot{q}_1}\right) - \frac{dT'}{dq_1} = -\frac{dV}{dq_1},$$

&c.

$$\frac{d}{dt}\left(\frac{dT'}{d\dot{q}_{n-3}}\right) - \frac{dT'}{dq_{n-3}} = -\frac{dV}{dq_{n-3}}.$$

In these equations the three objectionable coordinates do not appear, and thus the required elimination has been effected.

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Addition by Prof. Cayley.

The formulæ may be established in a somewhat different way, as follows:—

Consider the masses M_1, M_2, . . .

Let X_1, Y_1, Z_1 be the coordinates (in reference to a fixed origin and axes) of the C. G. of M_1;

x_1, y_1, z_1 the coordinates (in reference to a parallel set of axes through the C. G. of M_1) of an element m_1 of the mass M_1, and similarly for the masses M_2, . . .; the coordinates (X_1, Y_1, Z_1), (X_2, Y_2, Z_2), . . . all belonging to the same origin and axes;

And let $\dot{X}_1$ &c. denote the derived functions $\frac{dX_1}{dt}$ &c.

We have

$$T = S\tfrac{1}{2} m_1 [(\dot{X}_1+\dot{x}_1)^2+(\dot{Y}_1+\dot{y}_1)^2+(\dot{Z}_1+\dot{z}_1)^2]$$

$$+S\tfrac{1}{2} m_2 [(\dot{X}_2+\dot{x}_2)^2+(\dot{Y}_2+\dot{y}_2)^2+(\dot{Z}_2+\dot{z}_2)^2];$$

$$\vdots$$

or since $S m_1 x_1 = 0$ &c., and therefore also $S m_1 \dot{x}_1 = 0$ &c., this is

$$T = \tfrac{1}{2} M_1 (\dot{X}_1^2+\dot{Y}_1^2+\dot{Z}_1^2) \qquad +S\tfrac{1}{2} m_1 (\dot{x}_1^2+\dot{y}_1^2+\dot{z}_1^2)$$

$$+\tfrac{1}{2} M_2 (\dot{X}_2^2+\dot{Y}_2^2+\dot{Z}_2^2) \qquad +S\tfrac{1}{2} m_2 (\dot{x}_2^2+\dot{y}_2^2+\dot{z}_2^2)$$

$$\vdots \qquad\qquad\qquad \vdots$$

Write u, v, w for the coordinates of the C. G. of the whole system, then

$$M_1 X_1 + M_2 X_2 + \cdots = (M_1 + M_2 \cdots)\, u,$$

$$M_1 Y_1 + M_2 Y_2 + \cdots = (M_1 + M_2 \cdots)\, v,$$

$$M_1 Z_1 + M_2 Z_2 + \cdots = (M_1 + M_2 \cdots)\, w;$$

and thence

$$M_1 \dot{X}_1 + M_2 \dot{X}_2 + \cdots = (M_1 + M_2 \cdots)\, \dot{u},$$

$$M_1 \dot{Y}_1 + M_2 \dot{Y}_2 + \cdots = (M_1 + M_2 \cdots)\, \dot{v},$$

$$M_1 \dot{Z}_1 + M_2 \dot{Z}_2 + \cdots = (M_1 + M_2 \cdots)\, \dot{w};$$

and thence

$$T - \tfrac{1}{2}(M_1 + M_2 + \cdots)(\dot{u}^2+\dot{v}^2+\dot{w}^2)$$

$$= \frac{1}{M_1 + M_2 \cdots} \{M_1 M_2 [(\dot{X}_1-\dot{X}_2)^2+(\dot{Y}_1-\dot{Y}_2)^2+(\dot{Z}_1-\dot{Z}_2)^2]\}$$

$$\vdots$$

$$+S\tfrac{1}{2} m_1 (\dot{x}_1^2+\dot{y}_1^2+\dot{z}_1^2)$$

$$+S\tfrac{1}{2} m_2 (\dot{x}_2^2+\dot{y}_2^2+\dot{z}_2^2);$$

$$\vdots$$

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or, representing the function on the right-hand side by T', this is

$$T = \frac{1}{2}(M_1 + M_2 + \cdots)(\dot{u}_2 + \dot{v}_2 + \dot{w}_2) + T' \ldots, = T_0 + T'.$$

Suppose the positions are determined by means of the $6n$ coordinates $((q))$; the equations of motion are each of them of the form

$$\frac{d}{dt}\cdot\frac{dT_0}{d\dot{q}} - \frac{dT_0}{dq} + \frac{d}{dt}\cdot\frac{dT'}{d\dot{q}} - \frac{dT'}{dq} = -\frac{dV}{dq};$$

but these admit of further reduction; the part in T_0 depends upon three terms, such as

$$\frac{d}{dt}\left(\dot{u}\frac{d\dot{u}}{d\dot{q}}\right) - \dot{u}\frac{d\dot{u}}{dq}, = \frac{d\dot{u}}{dt}\frac{d\dot{u}}{d\dot{q}} + \dot{u}\left(\frac{d}{dt}\frac{d\dot{u}}{d\dot{q}} - \frac{d\dot{u}}{dq}\right).$$

But we have u a function of $((q))$, and thence

$$\frac{d\dot{u}}{d\dot{q}} = \frac{du}{dq}, \text{ or } \frac{d}{dt}\frac{d\dot{u}}{d\dot{q}} - \frac{d\dot{u}}{dq}, = \frac{d}{dt}\frac{du}{dq} - \frac{d\dot{u}}{dq}, = 0,$$

or the term is simply

$$= \frac{d\dot{u}}{dt}\frac{d\dot{u}}{dq}.$$

The equation thus becomes

$$(M_1 + M_2 \ldots)\left(\frac{d\dot{u}}{dt}\frac{d\dot{u}}{d\dot{q}} + \frac{d\dot{v}}{dt}\frac{d\dot{v}}{d\dot{q}} + \frac{d\dot{w}}{dt}\frac{d\dot{w}}{d\dot{q}}\right) + \frac{d}{dt}\frac{dT'}{d\dot{q}} - \frac{dT'}{dq} = -\frac{dV}{dq}.$$

Suppose now that T', V are functions of $6n-3$ out of the $6n$ coordinates $((q))$, and of the differential coefficients $\dot{q}$ of the same $6n-3$ coordinates, but are independent of the remaining three coordinates and of their differential coefficients; then, first, if q denotes any one of the three coordinates, the equation becomes

$$\frac{d\dot{u}}{dt}\frac{d\dot{u}}{d\dot{q}} + \frac{d\dot{v}}{dt}\frac{d\dot{v}}{d\dot{q}} + \frac{d\dot{w}}{dt}\frac{d\dot{w}}{d\dot{q}} = 0;$$

or, better,

$$\frac{d\dot{u}}{dt}\frac{du}{dq} + \frac{d\dot{v}}{dt}\frac{dv}{dq} + \frac{d\dot{w}}{dt}\frac{dw}{dq} = 0;$$

and the three equations of this form give

$$\frac{d\dot{u}}{dt} = 0, \quad \frac{d\dot{v}}{dt} = 0, \quad \frac{d\dot{w}}{dt} = 0,$$

viz., these are the equations for the conservation of the motion of the centre of gravity.

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And this being so, then, if q now denotes any one of the $6n-3$ coordinates, each of the remaining equations assumes the form

$$\frac{d}{dt}\cdot\frac{dT'}{d\dot{q}}-\frac{dT'}{dq}=-\frac{dV}{dq},$$

viz., we have thus $6n-3$ equations for the relative motion of the bodies of the system.

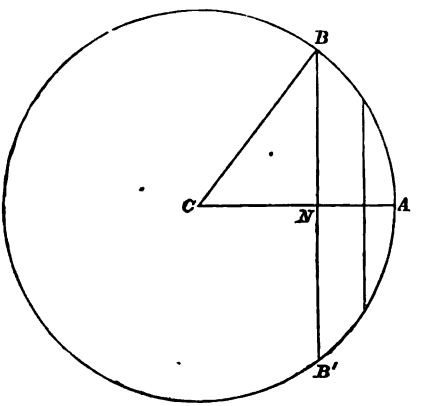
On Photographing Solar Transits by the use of the "Starlit Transit Eye-piece" formerly described; and other methods. By Dr. Royston-Pigott, M.A., F.R.S.

It may perhaps be recollected that the eye-piece contains a ruled micrometer, displaying equidistant parallel lines drawn on a silver film with great accuracy. At present the Sun transits in a five-feet telescope from line to line in five seconds—a second per foot of focal length.

If the image of the Sun in transits be projected on a screen of paper, a peculiar phenomenon is observed worth noting. So soon as the solar light illuminates the field, the transparent lines remain *black* until the sun flashes across the lines.

On the instant that the limb makes contact, a bright line is seen rapidly lengthening as a brilliant tangent, becoming a chord to the disk.

During the passage of the Sun across the bars, at each minute change of position the phases of the bars pass through a continual series of varying patterns.



If now an instantaneous photograph be taken at a known instant of time, the measured length of any one of these brilliant

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chords, and—still better—the measured lengths of several, may be employed accurately to determine the instant the Sun's centre would transit each particular bar.

Let C be the Sun's centre approaching the brilliant bar BB′ at the precise mean time M. Let BB′ be measured on the screen placed at a known fixed distance from the object-glass, so that the apparent diameter of the Sun may be assignable on the screen; so as to compare the length of the bar BB′ with the diameter of the Sun.

Then the time which will elapse before the centre of the Sun will transit over BB′ is (r being the semi-diameter of the Sun in time, θ the angle BCA, and $\frac{1}{2}\Delta$ being half the length of the bar)

$$t = \mathrm{CN} = r \cos \theta.$$

Also

$$\sin \theta = \frac{\mathrm{BN}}{\mathrm{BC}} = \frac{\frac{1}{2}\Delta}{r}.$$

Then the time of transit of Sun's centre over BB′ will be $\mathrm{M}+t$.

If several bars be measured on the photograph, say three

$$\mathrm{T, the\ mean\ time,} = \frac{1}{3}(t_1 + t_2 + t_3),$$

or

$$\mathrm{T} = \frac{r}{3} \cdot (\cos \theta_1 + \cos \theta_2 + \cos \theta_3);$$

and the final result for the time of passage of Sun's centre is $\mathrm{M}+\mathrm{T}$.

Should some of the bars be to the West and the others to the East, cos θ will have contrary signs algebraically.

Or if there are n bars measured, then, according to the usual notation,

$$\mathrm{T} = \frac{r}{n} \Sigma (\cos \theta).$$

Now, admitting that the lines are ruled very accurately (a thing not approached by mechanical arrangement of spider lines), any one of these lines should give the same instant of transit, because the centre passes each after equal intervals. By inspecting the tables of natural sines and tangents, it appears that, up to the first 18 minutes of arc, the tangents and sines are identical up to the $\frac{1}{10{,}000{,}000}$th of the radius, and the minutes of arc up to the semi-diameter of the Sun are equal within the

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$\frac{1}{10,000,000}$ th of the radius. From this it follows that the measurements of the bars, if drawn equidistant, for a telescope of 100 inches focus will not exhibit a tangential error exceeding the $\frac{1}{10,000}$th of an inch. At the full breadth of the image of the Sun—32 minutes—the error would be no greater. But as the field of view would probably not much exceed the semi-diameter, the tangential error from employing equidistant lines may be neglected.

The difficulty of ascertaining on the screen the precise magnitude of the Sun's semi-diameter may be avoided by using a screen at a standard distance from the focal point of the object-glass. And if a single uncemented triplet be used to throw the image upon the screen, whose focal length for simplicity is 1 inch, say at a distance of 10 inches from it, the usual formulæ for optical foci will give

$$\frac{1}{10}+\frac{1}{v}=\frac{1}{1}, \quad \text{or} \quad v=\frac{10}{9},$$

and the magnifying power on the screen will be

$$\frac{u}{v}=10\div\frac{10}{9}=9,$$

so that, at the distance of 10 inches from the eye-lens of the telescope (with a 1-inch triplet), the disk of the Sun will be magnified exactly *nine* times.

The actual size of the disk of the Sun at the focus of the telescope is readily obtained from the equation

$$D = F \sin \delta,$$

F being its focal length and δ the diameter of the Sun.

If the focal length be 60 inches, for example, and the Sun's diameter be 32′ 20″·2, the diameter on the screen will be

$$\delta = 9F \sin 32' 20''.2$$

$$\log \delta = \begin{cases} \log 9 & = 0.95424 \\ +\log 60 & = 1.77815 \\ +\log 32' 20''.2 & = 7.97334 \end{cases}$$

(rejecting the index) $10.70573 = 5.078$ inches

By a slight shifting of the screen, the Sun's image for the day may be made exactly to correspond with 5 inches. Should that be too large a photograph, then a telescope of shorter length can be used. At 6 inches distance the image will be magnified five

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times, just one time less than the number of inches of the screen from the lens, as seen from the formula

$$\frac{1}{d}+\frac{1}{v}=1,$$

for then

$$v=\frac{d}{d-1},$$

and the diameter of the Sun will be 2·821 inches. At 3 inches it will be magnified twice, and show a disk of diameter 1·128 inches. This very useful law for a 1-inch lens gives at once the magnifying power at any distance; say 30 inches distance from the lens, the image will be 29 times greater than the object in its focus.

Doubtless many methods will suggest themselves for utilising the appearance of the brilliant solar bars during observations for a transit. Suppose the photograph taken shortly before the time of central transit, so that the whole system of equidistant parallel bars are illuminated: the most favourable bar will evidently give the most exact position of the Sun's centre and the time of transit, viz. the bar or bars which give the smallest chords; for here they increase most rapidly.

Should the observer calculate the times from several bars, and take the mean of each, I presume this mean would scarcely differ from that obtained from the most favourable bar.

In photographing, the effect of obliquity of vision or parallax by displacement of the eye from the true optical axis is avoided. Also another error, irradiation, will so nearly affect both the disk of the Sun and the extremities of the brilliant bars as to lessen this source of error, which for *Venus* is about, I believe, half a second, and probably not much more for the Sun. Now half a second will not be much on the screen, and at each end of the bar this will make a whole second; and on a screen placed at 9 inches, this will with the telescope in question be one four-hundredth of an inch, and for a disk 2 inches in diameter it will be reduced to a thousandth. I do not therefore apprehend irradiation will be a serious error, if neglected. But it will be measurable by comparing a maximum bar with the Sun's calculated diameter on the screen.

In the case where a second photograph is taken after central transit, there will probably be great choice of verification bars. This method does not necessarily require the Sun-picture to be taken at the instant of transit.

But if such a system were preferred, a thin plate of glass placed at right angles to the axis, between the lens and the screen, and close behind the former, would both transmit the picture and reflect it to the observer in parallel rays by a suitable lens. The observer could then, by a spring, flash the photograph at the most favourable instant.

Supposing several bars are then chosen, avoiding those which

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are formed nearly equal to the diameter of the Sun, the determination of the distance of the Sun's centre from each of the chosen bars will be much facilitated by using the natural cosines of θ after determining the value of θ from the equation

$$\sin\theta = \frac{\frac{1}{2}\Delta}{r} = \frac{\text{half a bar}}{\text{rad. of Sun}}.$$

The foregoing equation

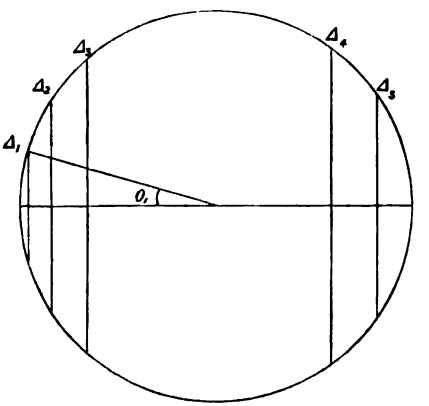
$$T = \frac{r}{n}\Sigma(\cos\theta)$$

will then give the time of transit of the Sun's centre, and the sign of the result, whether positive or negative, will show whether the time of observation is before or after the true transit. Moreover, should the first numerical differences not be exactly constant between $\cos\theta_1$, $\cos\theta_2$, $\cos\theta_3$, &c., two things may happen: either the lines are not ruled precisely equidistant, or else the measurement of the bars is untrue. For, since $t = r\cos\theta$, and r is constant, t varies as $\cos\theta$, so that $\cos\theta$ must increase exactly *pari passu* with the time the Sun has passed, or will reach a given bar.

After taking the sum of the natural cosines arithmetically, the final value of $\pm T = \frac{r}{n} \times$ sum of the cosines will of course be readily found by logarithms.

Probably sufficient accuracy (as perhaps diminishing the effect of irradiation) will be attained by preferring bars forming chords nearly subtending 60°, or equal to the Sun's radius.

A trigonometrical example may possibly interest some of our Fellows, and I therefore beg to submit one.



Let the bars

Δ_1	Δ_2	Δ_3	Δ_4	Δ_5
+18·2	+25·6	40·2	40	32·2

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be measured; determine the value of the times of transit of the Sun's centre over each bar: ($r = 32{\cdot}68$)

$$\sin\theta_1 = \Delta_1 + 2r = \frac{18{\cdot}2}{2\times 32{\cdot}68} = \frac{9{\cdot}1}{32{\cdot}68}$$

$$\log\sin\theta_1 = \left\{\begin{matrix}\bar{1}{\cdot}9590\\ -1{\cdot}5143\end{matrix}\right\} = 9{\cdot}4447,\ \theta_1 = 16^\circ\ 10'$$

$$\log\cos\theta_1 = 9{\cdot}9825$$

$$\log r\cos\theta_1 = \left\{\begin{matrix}1{\cdot}5143\\ +9{\cdot}9825\end{matrix}\right\} = 1{\cdot}4968,\ t_1 = \underline{31^s{\cdot}39}$$

$$\sin\theta_2 = \frac{12{\cdot}8}{32{\cdot}68},\ \log\sin\theta_2 = \left\{\begin{matrix}\bar{1}{\cdot}10721\\ -1{\cdot}51428\end{matrix}\right\} = 9{\cdot}59293,\ \theta_2 = \sin 23^\circ\ 4'$$

$$\left.\begin{matrix}\log\cos\theta_2 = 9{\cdot}9638\\ +\log r = +1{\cdot}5143\end{matrix}\right\} = 11{\cdot}4781,\ t_2 = \underline{30^s{\cdot}07}$$

$$\sin\theta_3 = \frac{20{\cdot}1}{32{\cdot}68},\ \log\sin\theta_3 = \left\{\begin{matrix}\bar{1}{\cdot}3031\\ -1{\cdot}5143\end{matrix}\right\} = 9{\cdot}7888,\ \theta_3 = 37^\circ\ 57'$$

$$t_3 = r\cos\theta_3\left\{\begin{matrix}\log\cos\theta_3 = 9{\cdot}8968\\ +\log r = +1{\cdot}5143\end{matrix}\right\} = 1{\cdot}4111,\ t_3 = \underline{25^s{\cdot}77}$$

$$\sin\theta_4 = \frac{20}{32{\cdot}68},\ \log\sin\theta_4 = \left\{\begin{matrix}\bar{1}{\cdot}3010\\ -1{\cdot}5143\end{matrix}\right\} = 9{\cdot}7867,\ \theta_4 = 37^\circ\ 44'$$

$$t_4 = r\cos\theta_4\left\{\begin{matrix}\log\cos\theta_4 = 9{\cdot}8981\\ +\log r = +1{\cdot}5143\end{matrix}\right\} = 11{\cdot}4124,\ t_4 = \underline{25^s{\cdot}85}$$

$$\sin\theta_5 = \frac{16{\cdot}1}{32{\cdot}68},\ \log\sin\theta_5 = \left\{\begin{matrix}\bar{1}{\cdot}2068\\ -1{\cdot}5143\end{matrix}\right\} = 9{\cdot}6925,\ \theta_5 = 29^\circ\ 31'$$

$$\left.\begin{matrix}\log\cos\theta_5 = 9{\cdot}9396\\ \log r = +1{\cdot}5143\end{matrix}\right\} = 1{\cdot}4539,\ t_5 = \underline{28^s{\cdot}44}$$

The bars Δ_1, Δ_2, Δ_3 lie east of Sun's centre and are negative. Times of Sun's centre passing the

Bars	Δ_1	Δ_2	Δ_3	Δ_4	Δ_5	if M be M.T. of transit.
M ±	$-31^s{\cdot}39$	$-30^s{\cdot}07$	$-25^s{\cdot}77$	25·85	28·45	
Differences	$1^s{\cdot}32$	$4^s{\cdot}30$	$51^s{\cdot}62$	$2^s{\cdot}60$		

By the microscope the intervals of each can be accurately measured with ease to the 10,oooth of an inch, as also the width of the cuts. By a low power, the photograph would probably yield the constant of irradiation for the given telescope, which, however, will probably vary with greater or less brilliancy of the Sun, and states of the atmosphere.

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The extremity of each bar will be projected outwards by the irradiation; while the breadth of a bar will be determined by mixed optical causes, such as diffraction and interference, as the peculiar darkness of the bright bands before illumination by the Sun particularly denotes. Again, the known diameter of the Sun compared with its image will be another method for determining readily this error.

I offer this method with great diffidence to the Society, having myself no practical knowledge of photography. Nor am I able to offer any valuable opinion whether this method of silver-film bars for transits is of any advantage. For myself, I have been contented with watching the very beautiful appearances of the transit of the Sun across these film bars, either projected on a screen or directly with a darkened eye-piece.

The method of direct observation by projection appears to have some advantages. The screen can readily be sketched with an exact copy of the illuminated bars, and divided into a scale of parts; the observer, at a given tick of the clock, can mark with a pencil the precise position of the extremity of a given bar. The diameter of the Sun may easily be enlarged to a foot. The lens spoken of as a triplet is an extraordinarily fine one, by Wray, formed of three glasses cemented to each other with balsam, and capable of displaying a very fine image of the Sun at 10 inches.

Should the solar heat melt the balsam, Mr. Wray can very readily construct these triplets without balsam. And if one of the interior surfaces is faintly blued with silver, the glass becomes a useful and beautifully defining eye-piece, though of small field. A large shade of pasteboard slipped over the object end of the telescope greatly improves the splendour and distinctness of the projected image of the Sun; and a number of transits across the bars, by the commencing flash and length, can be taken with great ease and comfort by the observer, the eye being entirely saved the heat, glare, and strain usual to the generally adopted method of spider lines. But, I again beg to repeat, I feel quite incompetent to form any opinion of the real value or utility of the methods now described.

I would add (while correcting the proof) that if the silver film be just the sufficient thickness or opacity to permit the outline of the limb of the Sun to be photographed, it is probable that nearly the whole of the irradiation of the limb may thus be destroyed, leaving that of the extremities of the bars in full irradiatory display.

The time can also afterwards, by the same translucent bars be compared with a star transit.

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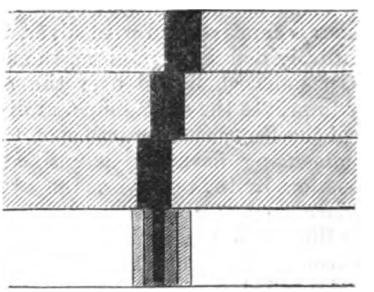
Effect of a Star's Rotation on its Spectrum.

By Capt. W. de W. Abney.

Having privately asked our President at the last meeting if he had considered the effect that would be produced by the rotation of a star on its spectrum, and having received a negative answer, I have ventured to bring the subject before the Society to provoke discussion if possible.

The light which radiates from every part of the visible surface of the star will fall on the slit of the spectroscope; hence a separate spectrum due to every portion of it will be formed. The advancing limb—supposing there is a rotation of the star—will cause the absorption lines to move towards the violet end, and the receding limb towards the red end of the spectrum; whilst the central portion will cause them to occupy their normal positions, provided there be no motion of the star in space.

As an example of what would occur, let us suppose the star's disk to be divided into three equal parts; one of which is advancing towards us, another receding at the same rate, and the third motionless. If we draw an exaggerated diagram of a small part of the spectra given by the light radiating from these three surfaces, we should get a result as shown.



There would be a total broadening of the line, consisting of a sort of double penumbra and a black nucleus. If the displacement was equal to half of the breadth of the line, the double penumbra alone would remain; whilst, if it were equal to the total breadth of the line, there would be only one penumbra. If we suppose the stellar surface to be equally bright throughout, we should get a graduated shade forming the penumbra; which would gradually melt off into the blacker nucleus which would form the line. I have calculated what the shade would be; but I have not thought it necessary to bring forward the formulæ to-night.

It seems, supposing the surface of a quickly rotating star

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to be in the same condition as the Sun as regards gaseous pressure and temperature, that no absorption line due to the former can be as sharp and distinct as it is when seen in the solar spectrum. More than this, rotation might account for the disappearance of some of the finer lines of the spectrum; and perhaps other phenomena observed may be attributable to the same cause. It appears also that, other conditions being known, the mean velocity of rotation might be calculated, or perhaps even the angular velocity. Since Dr. Huggins has commenced taking photographs of the spectra of stars, he may be able to give a thought to these points. I am convinced that from a good photograph much might be determined.

On the Variable Star U Geminorum. By G. Knott, Esq.

Mr. Hind's curious variable star, U *Geminorum*, has recently passed a *maximum*, of which I have obtained the following pretty complete series of observations:—

			h	m		Mag.
1877	February	16	11	40	G.M.T.	14·0
		17	7	30		14·0
		20	8	10		13·2
		21	10	30		9·8
		23	8	45		9·9
		25	10	0		9·9
		26	9	0		9·85
		27	9	0		9·9
		28	7	0		9·9
	March	1	7	35		9·95
		4	11	50		11·2
		5	10	30		11·7
		6	9	0		12·3
		8	8	0		13·7

The maximum was a rather faint one. The colour of the star throughout its apparition was white or bluish white, and on February 27 and March 4 was noted as *hazy*.

Cuckfield.
1877, *March* 9.

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Note on the Double Star ♅ I. 62. By S. W. Burnham, Esq.

The place of No. 62 of Sir William Herschel's Class I. is given in the Synopsis of his Catalogues (*Memoirs of the R.A.S.*, vol. xxxv.) for 1880, as :

R.A. = $20^h\ 58^m{\cdot}8$.

Decl. = $+6°\ 17'{\cdot}6$.

No measures of distance are recorded; but the angle was measured twice, 234°·8 in 1783·4, and 237°·1 in 1802·8. In the course of a search for the double stars of Herschel's Class I., not found in *Mensurae Micrometricae*, this was carefully looked for several times in and near the assigned place, but nothing of the kind could be found; and I became satisfied that in this, as in many other pairs previously identified, there was a considerable error in the place. It has since occurred to me that this is probably identical with No. 269 of my Fifth Catalogue of New Double Stars (*Monthly Notices*, November 1874), there being an error of 1° in Herschel's declination. The place of the new pair (1880) is :—

R.A. = $20^h\ 58^m\ 39^s$.

Decl. = $+7°\ 19'\ 6''$.

Baron Dembowski has measured this on three nights, giving a mean result (1875·1), P = 251°·0; D = 1″·11. The direct motion indicated by the two observations of Herschel would make the position-angle about 245° in 1875. As the pair is somewhat difficult, a small error in either of the single measures would fully account for this slight discrepancy. As similar mistakes in declination are not unfrequent in the lists of both Herschels, it may be considered as almost beyond doubt that these two pairs are identical. A continued advance in the angle will settle the question. There remains but one pair not yet accounted for of Herschel's Class I.

Chicago,
1877, *January* 23.

On the Magnitude of η Argûs. By J. Tebbutt, Esq.

In the *Monthly Notices*, vol. xxxi., p. 211, was published a series of comparisons of *η Argûs* made by me, and extending from July 1854 to the end of 1870. The following results are to be regarded as a continuation of that series, the comparison stars being contained in the Catalogue on page 42 of Sir J. Herschel's *Results of Astronomical Observations at the Cape of Good Hope*,

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1834–8, and embraced in the same field of view with *η Argûs*. It appears that *η Argûs* has diminished only about half a magnitude since 1870.

	Dates of the Comparisons.	Mean Date of Comparisons.	Mean of Concluded Mags.
1871	Jan. 14, 25, Feb. 13, March 20, April 3, 22, May 3, 16, 31, June 29	1871·26	6·37
1871	July 13, 14, 28, Aug. 31, Oct. 16, Nov. 25, Dec. 13, 29	1871·74	6·44
1872	Jan. 16, Feb. 20, March 8, April 5, May 9, 20, June 21, July 23, Aug. 20, Dec. 10	1872·40	6·49
1873	Feb. 4, 18, March 21, April 7, 22, 23, 24, May 1, 26, June 5, July 12, Aug. 5	1873·32	6·55
1874	Jan. 16, Feb. 18, March 19, April 17, May 13, 15, 21, 23, June 13, July 16, Nov. 19, Dec. 28	1874·42	6·58
1875	Jan. 28, March 19, May 13, 22, July 5, Aug. 17, Nov. 30, Dec. 18	1875·50	6·70
1876	June 17, 24, March 13, May 11, July 3, Aug. 31, Sept. 18, Nov. 21, Dec. 28	1876·44	6·70

Windsor, N. S. Wales,
1877, *January* 10.

On the Nomenclature of Meteor Radiant Points.

By J. W. Backhouse.

The proper naming of meteor showers is a subject of some importance, on account of the confusion that must result if unsuitable names are given to them. It therefore appears to me that it should not be left to individual astronomers to give names, or we shall have such ones as are found in the January Number of the *Monthly Notices*, pp. 108–111. In that paper there are several cases in which two different showers are called by the same name; and we find such names as *Taurids I.*, *Taurids II.*, *Leonids Minor*, &c.

I would suggest that the nomenclature of radiant points should be placed in charge of the British Association Committee on Luminous Meteors; though I do not know what foreign astronomers would say to this, seeing that they might be inclined to adopt the English names, or similar ones, on condition of their being suitably chosen. It is probably not needful that many showers should be named; but it seems most suitable that whoever wishes to have any named should communicate with that Committee.

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On the Relative Space-penetrating Power of Reflectors and Refractors. By the Rev. T. R. Robinson, D.D.

I have at last obtained access to the Memoir in the *Bulletin de l'Académie de St.-Pétersbourg* to which M. Struve refers me.

It shows that M. Radau did not make the mistake which I imputed to him. I may be excused for having done so, because I did not conceive it possible that one whose authority is so high as M. O. Struve's deservedly is could assert that a 4-feet reflector of first rate excellence had scarcely higher power than a 15-inch refractor.

I was proceeding to show that the observations recorded in this Memoir lead to a conclusion the very reverse of M. Struve's, when I saw in the *Monthly Notices* that Mr. Lassell has so completely disposed of the question that such examination of them is quite unnecessary.

But I will give some facts relative to another 4-feet, the Great Melbourne Telescope, which throw some light on the question. The American astronomers who observed the Transit of *Venus* visited Melbourne, and report of that instrument to Professor Newcomb that "its definition is good; its optical power comparable to the 26-inch refractor; sky is black close to large stars instead of the blue light of the secondary spectrum shown by the great refractor; and that the distant companion of *Procyon* could have been seen close up to *Procyon* itself."

It should be mentioned that this speculum has not been repolished for several years, though it has been in constant use.

Armagh,
1877, *February* 8.

Erratum.

Vol. xxxvi. p. 361, middle:

for $-1''\cdot50$ and $-1''\cdot50$ read in each case $+1''\cdot50$.

viz. the correction to the longitude is

$$\delta v = +1''\cdot50 \sin(g + N - 90^\circ).$$

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. APRIL 13, 1877. No. 6.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Frederick Newton, Esq., Hill Side Lawn, Hornsey Lane, was balloted for and duly elected a Fellow of the Society.

On a Peculiarity of Personal Equation.

By Capt. W. M. Campbell, R.E.

The following remarks on what is to me a novel feature of "Personal Equation" may prove of some interest.

From the end of 1875 I have been employed, in association with Capt. Heaviside, R.E., on the determination of differential longitudes in India, by means of the Electric Telegraph.

In such operations, Personal Equation being a matter of first importance, we devoted nine nights, at intervals throughout the course of observations in 1875–6, to the determination of our relative equation.

The method followed was always that of "divided transits," in which one observer takes the first portion of a star's transit, and the second finishes the observation at the same telescope.

I should note that the transit instruments used are powerful telescopes, by Cooke & Sons, of about 5 ft. focal length, with 5-in. objectives.

The wires are 25 in number, in tallies of 5 each, the intervals being about $2\frac{1}{2}$ sec. between wires, and 5 sec. between tallies.

We always observed with an oblique eye-piece, so that the line of sight was at right angles to the axis of the telescope, and stars were observed with their actual motion.

A chronograph being used, it is easy for observers to change places in the middle of a transit, observing it over the first and last 10 wires respectively, supposing, at least, that no change is

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required in the adjustment for focus of eye-piece. In taking a set of such transits (we generally took 20 on each night), the order of observation was alternated; thus the observer who took the last part of one transit observed the first portion of the next.

The value of our relative equation, adopted from all such observations, was $C-H = +0^{s}\cdot064 \pm 0^{s}\cdot0057$, Capt. Heaviside observing in advance of me.

When near the completion of the reduction of our observations of 1875–6 generally, we discovered that we had two distinct equations when observing imitation transits, according as the motion of the object was from right to left or left to right.

This led to a re-discussion of all the observations of "divided transits," arranged in two sets—viz. North Zenith Stars, or those moving from right to left, and South Zenith Stars, or those moving from left to right—with the following results:—

$$\text{By NZ Stars, } C-H = +0^{s}\cdot124 \pm 0^{s}\cdot0087$$
$$\text{„ SZ „ } C-H = +0^{s}\cdot040 \pm 0^{s}\cdot0034$$

The application of these equations, instead of the one first adopted, very much improved our general results.

On resuming observations this season—1876–7, we agreed to observe every close Zenith star on both sides, i.e. to observe it as a North Zenith star over the first 10 wires, and then, reversing the eye-piece, to take it as a South star over the last 10 wires, or *vice versâ*, stars being observed in each order nearly equally.

From 21 stars observed by me in this way during January, I find my equation to be

$$N-S = +0^{s}\cdot077 \pm 0^{s}\cdot0067$$

my observation of North stars, moving from right to left, being slower than that of South, or left to right moving, stars by $0^{s}\cdot077$. I have not yet heard the result of similar observations by Capt. Heaviside.

Bombay,
1877, *March* 19.

Observations of the Phenomena of Jupiter's Satellites at the Observatory, Adelaide, and Notes on the Physical Appearance of the Planet. By Charles Todd, Esq., C.M.G.

The Astronomer Royal has received from Charles Todd, Esq., of the Observatory, Adelaide, the following communication and observations of *Jupiter's* Satellites:—

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"Enclosed I send you, for the Royal Astronomical Society, my first contribution of observations of *Jupiter's* Satellites, and a few rough sketches made at the Adelaide Observatory this year. I hope to do better at next opposition.

"In connection with these observations there are two or three things which may be worth mentioning, as I am not sure they have been so well seen before.

"On one or two occasions when a satellite has been on the point of occultation, it has appeared to be projected on the disk of the planet; or rather, as it appeared independently to my assistant (Mr. Ringwood) and myself, as if seen *through* the edge of the planet, as if the latter were surrounded by a transparent atmosphere laden with clouds. I noticed this on two occasions, viz. on August 21, at the disappearance of the 1st satellite, when the satellite was distinctly seen on or through the edge of the disk for about 2 minutes before disappearance—I say *through* the edge of the disk because the satellite was less bright than in a similar position at a transit—and again at the disappearance of the 2nd satellite on August 28. Mr. Ringwood also noticed it on August 12 and August 19, at occultation of 1st and 3rd satellites. In each instance the planet was splendidly defined—better than I ever remember to have seen it in England. It was not noticed at any reappearance which took place at the eastern or defective limb; the gibbosity of the planet was, however, quite sensible at reappearance, when the planet was near quadrature—*vide* Oc. R. of 3rd satellite on August 19, and of 2nd satellite on August 21, when the satellite at instant of emergence was sensibly separated from the illuminated edge of the planet.

"The shadow of the 3rd satellite, when in mid-transit along a high northern parallel on August 30, appeared to me to be visibly oval or flattened at its poles, the definition being all that could be desired. On several occasions at ingress of shadow I was surprised at the marvellous sharpness, the minutest indentation of the limb being at once detected.

"The phenomena on August 21 were singularly beautiful; the 2nd satellite, as it emerged from behind the planet, immediately passed into the shadow, subsequently reappearing within a few minutes of the reappearance of and close to the 1st satellite; the two forming a pretty coarse double star.

"The sketches, which were taken for the Jovian Committee of the Royal Astronomical Society, are perhaps not worth much, but they are fairly faithful. I was much impressed on some nights with the sudden and extensive changes in the cloud belts, as though some tremendous storm was in progress on the planet's surface, changing the form and dimensions of the cloud belts in an hour or two, or even less. I hope to do better next year, but trust that this humble contribution to Jovian Astronomy may not be without interest."

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Observations of Eclipses, Occultations, and Transits of Jupiter's Satellites, made with the 8-in. Equatoreal (Cooke) at the Adelaide Observatory, South Australia.

	h	m	s	
Longitude	9	14	21·3	East.
	°	′	″	
Latitude	34	55	33·8	South.

1876.

Reference No.	Observer.	Day of Observation. 1876	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding Greenwich Mean Time. h m s	Greenwich Mean Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
1	T	June 13	I	Oc. D.	External contact	6 21 9·50	21 6 48·20			200
2	„	„ „	„	„	Bisected	6 23 4·50	21 8 43·20	21 14		„
3	„	„ „	„	„	Internal contact	6 27 32·00	21 13 10·70			„
4	T	„ 22	I	Ec. R.	First seen	5 37 39·35	20 23 18·05	20 23 30·4	+0 12·35	„
5	T	„ 23	III	Ec. R.	First seen	6 24 43·80	21 10 22·50	21 14 5·9	+3 43·40	„
6	T	„ 25	II	Ec. R.	First seen	12 54 45·80	3 40 24·50	3 43 11·2	+2 46·70	„
7	T	„ 28	I	Tr. I.	External contact	7 9 22·10	21 55 0·80			„
8	„	„ „	„	„	Bisected	7 11 30·10	21 57 8·80	21 55		„
9	„	„ „	„	„	Internal contact	7 13 18·10	21 58 56·80			„
10	T	„ „	I	Tr. E.	Internal contact	9 15 51·94	0 1 30·64			,
11	„	„ „	„	„	Bisected	9 18 26·94	0 4 5·64	0 8		„
12	„	„ „	„	„	External contact	9 20 20·43	0 5 59·13			„
13	T	„ „	I	Sh. E.	Internal contact	10 10 33·36	0 56 12·06			„
14	„	„ „	„	„	Limb indented	10 12 24·86	0 58 3·56	1 2		„
15	„	„ „	„	„	Limb complete	10 13 23·86	0 59 2·56			„

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16	T	„ 29	I	Ec. R.	First seen	7 32 27·15	22 18 5·85		22 18 1·8	−0 4·05	„
17	T	July 4	II	Tr. I.	External contact	6 1 8·88	20 46 47·58				„
18	„	„ „	„	„	Bisected	6 2 58·38	20 48 37·08		20 45		„
19	„	„ „	„	„	Internal contact	6 5 37·88	20 51 16·58				„
20	T	„ „	II	Sh. I.	First seen	8 0 10·68	22 45 49·38				„
21	„	„ „	„	„	Shadow bisected (?)	8 1 30·68	22 47 9·38		22 44		„
22	„	„ „	„	„	Internal contact	8 3 59·38	22 49 38·08				„
23	T	„ „	II	Tr. E.	Internal contact	8 29 16·63	23 14 55·33				„
24	„	„ „	„	„	Satellite bisected (?)	8 31 33·13	23 17 11·83		23 19		„
25	„	„ „	„	„	External contact	8 33 37·63	23 19 16·33				„
26	T	„ „	II	Sh. E.	Internal contact	10 24 51·14	1 10 29·84				„
27	„	„ „	„	„	Limb indented	10 26 40·94	1 12 19·64		1 20		„
28	„	„ „	„	„	Limb complete	10 28 57·14	1 14 35·84				„

Remarks.

Ref. No.
1 Very difficult observation.
2 Uncertain; difficult to say when exactly bisected.
3 Uncertain observation; eye very tired.
4 Very exact; first speck of light.
5 Very exact; planet splendidly defined.
6 Very exact.
7, 8, 9 } Good observations.
10, 11, 12 } Good observations.

Ref. No.
13 Good observation.
14 Limb of planet indented by shadow.
16 Seen through cloud, but considered good.
20 Shadow first seen.
21 Limb plainly indented; shadow considered to be bisected.
22 Good observation; limb and shadow sharply defined, but clouds passing over planet.
23, 24, 25 } Very good observations; beautifully defined.

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Reference No.	Observer.	Day of Observation. 1876	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding Greenwich Mean Time. h m s	Greenwich Mean Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
29	T	July 5	I	Tr. I.	External contact	8 56 24·00	23 42 2·70			200
30	,,	,, ,,	,,	,,	Bisection (?)	8 58 33·80	23 44 12·50	23 44		,,
31	,,	,, ,,	,,	,,	Internal contact	9 0 28·50	23 46 7·20			,,
32	T	,, ,,	I	Sh. I.	First seen	9 57 12·40	0 42 51·10			,,
33	,,	,, ,,	,,	,,	Limb indented	9 58 43·90	0 44 22·60	0 44		,,
34	,,	,, ,,	,,	,,	Internal contact	10 1 6·10	0 46 44·80			,,
35	R	,, 7	I	Sh. E.	Internal contact	6 34 23·93	21 20 2·63			,,
36	,,	,, ,,	,,	,,	Bisection (?)	6 35 51·43	21 21 30·13	21 26		,,
37	,,	,, ,,	,,	,,	Limb complete	6 37 26·43	21 23 5·13			,,
38	T	,, 12	I	Tr. I.	Internal contact	10 51 7·33	1 36 46·03	1 34		,,
39	R	,, 13	II	Ec. R.	First seen	7 28 15·85	22 13 54·55			,,
40	,,	,, ,,	,,	,,	Quite distinct	7 29 29·85	22 15 8·55	22 16 34·0	+2 39·45	,,
41	,,	,, ,,	,,	,,	Full blaze (?)	7 30 13·85	22 15 52·55			,,
42	R	,, ,,	I	Oc. D.	External contact	8 3 4·80	22 48 43·50			,,
43	,,	,, ,,	,,	,,	Bisection (?)	8 4 47·80	22 50 26·50			,,
44	,,	,, ,,	,,	,,	Disappearance	8 7 27·30	22 53 6·00	22 51		,,
45	R	,, ,,	I	Ec. R.	First seen	11 21 13·50	2 6 52·20			,,
46	,,	,, ,,	,,	,,	Quite distinct	11 23 23·50	2 9 2·20	2 7 15·5	+0 23·30	,,
47	,,	,, ,,	,,	,,	Full blaze (?)	11 24 13·00	2 9 51·70			,,

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48	T	„	14	I	Sh. I.	First seen	6 22 58·86	21 8 37·56					125
49	„	„	„	„	„	Bisection (?)	6 23 25·66	21 9 4·36	21 8				„
50	„	„	„	„	„	Internal contact	6 25 22·66	21 11 1·36					„
51	T	„	„	I	Tr. E.	Internal contact	7 26 39·55	22 12 18·25					„
52	„	„	„	„	„	Bisection (?)	7 28 9·25	22 13 47·95	22 14				„
53	„	„	„	„	„	External contact	7 29 56·05	22 15 34·75					„
54	T	„	18	II	Tr. I.	External contact	10 49 16·44	1 34 55·14	1 33				200
55	„	„	„	„	„	Internal contact	10 55 13·74	1 40 52·44					„
56	T	„	20	I	Oc. D.	External contact	9 51 26·89	0 37 5·59	0 41				„
57	„	„	„	„	„	Disappearance	9 58 1·89	0 43 40·59					„
58	T	„	„	II	Ec. R.	First seen	10 5 29·08	0 51 7·78					„
59	„	„	„	„	„	Quite distinct	10 6 21·88	0 52 0·58	0 54	1·4	+2 53·62		„
60	„	„	„	„	„	Full blaze (?)	10 9 26·88	0 55 5·58					„

Remarks.

Ref. No.

29 Good.
31 Very good observation.
32 Shadow first seen.
33 Shadow bisected.
34 Limb complete.
36 Limb of planet indented.
37 Limb complete; external contact.
38 Very good observation; external contact lost; too late.
42, 43 Good observations; planet and satellite splendidly defined.
44 The satellite was seen for some seconds as a very fine point of light and suddenly disappeared at time noted, which was considered very exact.

Ref. No.

45 Very good observation.
47 About full blaze.
48 A little way on limb of planet; planet badly defined throughout this phenomenon; could use only power 125.
51, 52, 53 Very badly defined and unsteady.
54 Very unsteady; satellite continually jumping off and on planet.
55 Very good observation.
58 First glimmer; very exact; thin clouds occasionally passing over planet; observation considered good.

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Reference No.	Observer.	Day of Observation.	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Greenwich Mean Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
		1876				h m s	h m s	h m s	m s	
61	T	July 21	I	Tr. I.	External contact	7 5 10·70	21 50 49·40			200
62	,,	,, ,,	,,	,,	Bisection (?)	7 7 0·70	21 52 39·40	21 52		,,
63	,,	,, ,,	,,	,,	Internal contact	7 9 21·70	21 55 0·40			,,
64	T	,, ,,	I	Sh. I.	First seen	8 17 39·58	23 3 18·28			,,
65	,,	,, ,,	,,	,,	Bisection (?)	8 18 41·58	23 4 20·28	23 3		,,
66	,,	,, ,,	,,	,,	Internal contact	8 20 38·58	23 6 17·28			,,
67	T	,, ,,	I	Tr. E.	Internal contact	9 13 37·50	23 59 16·20			,,
68	,,	,, ,,	,,	,,	Bisection (?)	9 16 43·50	0 2 22·20	0 5		,,
69	,,	,, ,,	,,	,,	External contact	9 18 44·50	0 4 23·20			,,
70	T	,, ,,	I	Sh. E.	Internal contact	10 22 16·38	1 7 55·08			,,
71	,,	,, ,,	,,	,,	Bisection (?)	10 24 16·88	1 9 55·58	1 16		,,
72	,,	,, ,,	,,	,,	Limb complete	10 26 18·88	1 11 57·58			,,
73	T	,, 28	I	Tr. I.	External contact	8 56 34·47	23 42 13·17			,,
74	,,	,, ,,	,,	,,	Bisection (?)	8 58 44·77	23 44 23·47	23 45		,,
75	,,	,, ,,	,,	,,	Internal contact	9 1 12·27	23 46 50·97			,,
76	T	,, 30	I	Sh. E.	Internal contact	6 46 34·93	21 32 13·63			,,
77	,,	,, ,,	,,	,,	Bisection (?)	6 48 54·93	21 34 33·63	21 40		,,
78	,,	,, ,,	,,	,,	Limb complete	6 50 54·93	21 36 33·63			,,
79	T	Aug. 1	III	Tr. I.	External contact	9 6 51·63	23 52 30·33			,,
80	,,	,, ,,	,,	,,	Bisection (?)	9 9 43·13	23 55 21·83	0 1		,,
81	,,	,, ,,	,,	,,	Internal contact	9 17 5·93	0 2 44·63			,,

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82	R	„	12	III	Oc. R.	External contact	5 19 30·26	20 5 8·96		20 10		„
83	R	„	„	II	Tr. I.	External contact	7 36 23·00	22 22 1·70				„
84	„	„	„	„	„	Bisection	7 37 50·00	22 23 28·70		22 17		„
85	„	„	„	„	„	Internal contact	7 40 38·50	22 26 17·20				„
86	R	„	„	III	Ec. D.	Satellite just visible	8 39 29·86	23 25 8·56		23 20 33·0	−5 3·56	„
87	„	„	„	„	„	Disappearance	8 39 57·86	23 25 36·56				„
88	R	„	„	I	Oc. D.	External contact	9 59 36·72	0 45 15·42				„
89	„	„	„	„	„	Bisection (?)	10 1 8·72	0 46 47·42		0 47		„
90	„	„	„	„	„	Disappearance	10 3 58·72	0 49 37·42				„
91	R	„	„	II	Tr. E.	Internal contact	10 8 20·70	0 53 59·40				„
92	„	„	„	„	„	Bisection (?)	10 9 17·70	0 54 56·40		0 54		„
93	„	„	„	„	„	External contact	10 9 54·70	0 55 33·40				„
94	R	„	„	II	Sh. I.	First seen	10 10 4·20	0 55 42·90				„
95	„	„	„	„	„	Limb indented	10 11 54·70	0 57 33·40		0 54		„
96	„	„	„	„	„	Internal contact	10 12 4·70	0 57 43·40				„

Remarks.

Ref. No.

63 Good observation.
66 Limb complete.
67 May be a little early.
69 Very exact; good observation.
70, 71, 72 Limb very unsteady and only well defined occasionally, rendering observation extremely difficult.
73 Good observation.
75 Good observation.
78 Last seen; limb complete; good; planet's limb very sharply defined.
82 Rather late; much before expected time; when seen the whole of the satellite was visible.
87 Last seen; good observation.
90 For several seconds before disappearance the satellite seemed to be visible inside limb of planet, as if projected on planet.
94 The limb a little indented.
96 Limb complete; may be a little late.

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Reference No.	Observer.	Day of Observation.	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Greenwich Mean Time by *Nautical Almanac*.	Apparent Error of *Nautical Almanac*.	Power.
		1876				h m s	h m s	h m s	m s	
97	R	Aug. 12	III	Ec. R.	First seen	10 21 0·68	1 6 39·38			200
98	„	„ „	„	„	Quite distinct	10 22 54·18	1 8 32·88	1 10 47·4	+4 8·02	„
99	„	„ „	„	„	Full blaze (?)	10 23 55·68	1 9 34·38			„
100	R	„ 13	I	Tr. I.	External contact	7 12 20·80	21 57 59·50			„
101	„	„ „	„	„	Bisection (?)	7 14 46·80	22 0 25·50	22 1		„
102	„	„ „	„	„	Internal contact	7 16 59·80	22 2 38·50			„
103	R	„ „	I	Sh. I.	First seen	8 32 23·65	23 18 2·35			„
104	„	„ „	„	„	Bisection (?)	8 33 8·65	23 18 47·35	23 18		„
105	„	„ „	„	„	Limb complete	8 33 56·65	23 19 35·35			„
106	R	„ „	I	Tr. E.	Internal contact	9 25 41·52	0 11 20·22			„
107	„	„ „	„	„	Bisection (?)	9 27 25·52	0 13 4·22	0 14		„
108	„	„ „	„	„	External contact	9 28 13·52	0 13 52·22			„
109	R	„ 14	II	Ec. R.	First seen	7 17 6·95	22 2 45·65			„
110	„	„ „	„	„	Quite distinct	7 17 33·95	22 3 12·65	22 5 19·1	+2 33·45	„
111	„	„ „	„	„	Full blaze (?)	7 18 48·95	22 4 27·65			„
112	R	„ „	I	Ec. R.	First seen	7 57 21·87	22 43 0·57			
113	„	„ „	„	„	Quite distinct	7 57 58·87	22 43 37·57	22 43 31·6	+0 31·03	„
114	„	„ „	„	„	Full blaze (?)	7 58 58·87	22 44 37·57			„
115	R	„ 19	III	Oc. D.	External contact	7 8 16·80	21 53 55·50			,
116	„	„ „	„	„	Bisection (?)	7 12 40·30	21 58 19·00	21 57		„
117	„	„ „	„	„	Disappearance	7 19 46·30	22 5 25·00			„

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118	R	„	„	III	Oc. R.	First seen	9 17 35·05	0 3 13·75			„
119	„	„	„	„	„	Bisection (?)	9 20 47·55	0 6 26·25		0 10	„
120	„	„	„	„	„	External contact (?)	9 28 15·55	0 13 54·25			„
121	T	„	20	I	Tr. I.	External contact	9 8 15·30	23 53 54·00			„
122	„	„	„	„	„	Bisection	9 10 20·30	23 55 59·00		23 56	„
123	„	„	„	„	„	Internal contact	9 12 37·30	23 58 16·00			„
124	T	„	21	I	Oc. D.	External contact	6 23 52·24	21 9 30·94			„
125	„	„	„	„	„	Bisection (?)	6 25 41·54	21 11 20·24		21 11	„
126	„	„	„	„	„	Disappearance	6 27 57·54	21 13 36·24			„

Remarks.

Ref. No.

97 Very good observation; first seen as a minute speck of light.

100, 101, 102 Good observations; well defined.

103 Very good.

108 Could not obtain egress of shadow; last seen about twice its diameter from limb of planet; power 125.

109 Very good observation; suddenly appearing as a very minute speck of light.

112 Good observation; suddenly appearing as a very minute speck of light.

115 Very steady and well defined.

116 Appeared as a well-defined nipple protruding from planet; very steady and well defined.

Ref. No.

117 Very good; steady and well defined; suddenly disappearing; satellite appeared as if projected on planet, and in internal contact a full minute before its final disappearance.

118 First seen as a fine point of light, a little outside limb of planet; throughout this phenomenon, which was very good and well defined, there was a dark line or sensible space between satellite and limb of planet.

121, 122, 123 Very good and well defined.

124, 125, 126 Very good; steady and well defined; after bisection the satellite was seen as if projected on limb of planet.

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Reference No.	Observer.	Day of Observation. 1876	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time. h m s	Corresponding Greenwich Mean Time. h m s	Greenwich Mean Time by *Nautical Almanac*. h m s	Apparent Error of *Nautical Almanac*. m s	Power.
127	T	Aug. 21	II	Oc. R.	First seen	7 18 55·43	22 4 34·13			200
128	,,	,, ,,	,,	,,	Bisection (?)	7 19 51·93	22 5 30·63	22 8		,,
129	,,	,, ,,	,,	,,	External contact (?)	7 22 40·43	22 8 19·13			,,
130	T	,, ,,	II	Ec. D.	Disappearance	7 23 55·42	22 9 34·12	22 8 54·3	−0 39·82	,,
131	T	,, ,,	I	Ec. R.	First seen	9 52 23·16	0 38 1·86			125
132	,,	,, ,,	,,	,,	Quite distinct	9 53 52·16	0 39 30·86	0 38 17·3	+0 15·44	,,
133	,,	,, ,,	,,	,,	Full blaze (?)	9 55 54·16	0 41 32·86			,,
134	T	,, ,,	II	Ec. R.	First seen	9 55 19·16	0 40 57·86			,,
135	,,	,, ,,	,,	,,	Quite distinct	9 57 21·15	0 42 59·85			,,
136	,,	,, ,,	,,	,,	I and II Satellites equally bright	9 58 1·15	0 43 39·85	0 43 5·9	+2 8·04	,,
137	,,	,, ,,	,,	,,	Full blaze (?)	9 59 49·15	0 45 27·85			,,
138	R	,, 22	I	Sh. E.	Internal contact	7 2 26·62	21 48 5·32			200
139	,,	,, ,,	,,	,,	Bisection (?)	7 3 41·62	21 49 20·32	21 55		,,
140	,,	,, ,,	,,	,,	Limb complete	7 6 1·62	21 51 40·32			,,
141	T	,, 28	II	Oc. D.	External contact	7 20 55·60	22 6 34·30			,,
142	,,	,, ,,	,,	,,	Bisection (?)	7 22 29·30	22 8 8·00	22 11		,,
143	,,	,, ,,	,,	,,		7 24 5·60	22 9 44·30			,,
144	,,	,, ,,	,,	,,	Disappearance	7 25 59·60	22 11 38·30			,,

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145	T	„	„	I	Oc. D.	External contact	8 19 19·47	23 4 58·17					„
146	„	„	„	„	„	Bisection (?)	8 20 56·97	23 6 35·67		23 7			„
147	„	„	„	„	„	Disappearance	8 23 38·97	23 9 17·67					„
148	T	„	29	I	Sh. I.	First seen	6 51 57·52	21 37 36·22					„
149	„	„	„	„	„	Internal contact	6 54 45·52	21 40 24·22		21 38			„
150	T	„	„	I	Tr. E.	Internal contact	7 45 15·90	22 30 54·60					„
151	„	„	„	„	„	Bisection (?)	7 46 56·90	22 32 35·60		22 35			„
152	„	„	„	„	„	External contact	7 48 59·90	22 34 38·60					„
153	T	„	30	I	Ec. R.	First seen	6 15 36·57	21 1 15·27					„
154	„	„	„	„	„	Quite distinct	6 16 17·07	21 1 55·77		21 1 44·9		+0 29·63	„
155	„	„	„	„	„	Full blaze (?)	6 19 7·07	21 4 45·77					„

Remarks.

Ref. No.

127 Quite a minute late (?) emerging at a sensible distance from limb or edge of planet.

128 Immediately after this, the satellite commenced to diminish in brightness; entering shadow.

129 Supposed external contact, but satellite becoming very dim, as it entered shadow immediately after reappearance.

130 Very exact; close to limb of planet, to which it appeared to cling as it diminished in brightness.

134 The second satellite reappeared before the first was full blaze.

136 The two satellites equal in brightness, and about 1½ to 2 diameters apart, appearing as a pretty double star; these two phenomena were very good observations, steady and well defined.

Ref. No.

138 Not very good; limb very unsteady.

139 Fair observation.

140 Supposed external contact.

143 Satellite quite distinctly seen, as if projected on planet.

144 Last seen.

145 Not very good; hazy, and thin cloud over sky; planet and satellite unsteady; good only in glimpses.

148 When first seen nearly bisected.

149 A very good observation; planet fairly well defined.

152 A very good observation; could not make out the shadow at egress.

153 Very good.

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	Observer.	Day of Observation. 1876	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Greenwich Mean Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
						h m s	h m s	h m s	m s	
156	T	Aug. 30	III	Sh. I.	First seen	6 18 54·57	21 4 33·27			200
157	,,	,, ,,	,,	,,	Limb indented	6 25 57·54	21 11 36·24	21 5		,,
158	,,	,, ,,	,,	,,	Internal contact	6 27 47·04	21 13 25·74			,,
159	T	,, ,,	II	Sh. E.	Internal contact	7 3 17·95	21 48 56·65			,,
160	,,	,, ,,	,,	,,	Limb broken	7 4 36·95	21 50 15·65			,,
161	,,	,, ,,	,,	,,	Bisection (?)	7 5 43·95	21 51 22·65	21 58		,,
162	,,	,, ,,	,,	,,	Limb complete	7 7 21·95	21 53 0·65			,,
163	T	,, ,,	III	Sh. E.	Internal contact	8 3 52·80	22 49 31·50			,,
164	,,	,, ,,	,,	,,	Limb broken	8 5 47·80	22 51 26·50			,,
165	,,	,, ,,	,,	,,	Bisection (?)	8 9 26·80	22 55 5·50			,,
166	,,	,, ,,	,,	,,	Limb indented	8 13 28·80	22 59 7·50	23 10		,,
167	,,	,, ,,	,,	,,	Limb indented	8 14 52·30	23 0 31·00			,,
168	,,	,, ,,	,,	,,	Limb complete	8 17 5·80	23 2 44·50			,,
169	R	Sept. 5	I	Tr. I.	External contact	7 32 30·97	22 18 9·67			,,
170	,,	,, ,,	,,	,,	Bisection (?)	7 33 43·97	22 19 22·67	22 20		,,
171	,,	,, ,,	,,	,,	Internal contact	7 35 19·47	22 20 58·17			,,
172	T	,, 6	II	Sh. I.	First seen	7 11 42·30	21 57 21·00			,,
173	,,	,, ,,	,,	,,	Internal contact	7 14 54·30	22 0 33·00	21 55		,,
174	T	,, ,,	II	Tr. E.	Internal contact	7 15 48·80	22 1 27·50			,,
175	,,	,, ,,	,,	,,	Bisection (?)	7 19 20·30	22 4 59·00	22 4		,,
176	,,	,, ,,	,,	,,	External contact	7 22 5·29	22 7 43·99			,,

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177	T	„	„	III	Tr. E.	Internal contact	7 21 13·79	22 6 52·49				„
178	„	„	„	„	„	Bisection (?)	7 25 39·29	22 11 17·99		22 21		„
179	„	„	„	„	„	External contact	7 33 30·28	22 19 8·98				„
180	T	„	„	I	Ec. R.	First seen	8 10 22·20	22 56 0·90				„
181	„	„	„	„	„	Quite distinct	8 10 59·20	22 56 37·90		22 56 29·6	+0 28·70	„
182	„	„	„	„	„	Full blaze (?)	8 14 14·20	22 59 52·90				„
183	R	„	13	II	Tr. I.	External contact	7 24 42·05	22 10 20·75				„
184	„	„	„	„	„	Bisection (?)	7 26 50·05	22 12 28·75		22 7		„
185	„	„	„	„	„	Internal contact	7 20 2·55	22 15 41·25				„
186	T	„	17	III	Ec. R.	First seen	6 18 30·32	21 4 9·02		21 8 48·4	+4 39·38	125
187	„	„	„	„	„	Full blaze (?)	6 28 41·61	21 14 20·31				„

Remarks.

Ref. No.

156 When first seen limb sensibly indented, as I was watching for full blaze of first satellite.
158 Limb complete, definition excellent.
162 Limb complete; throughout this observation, which was very good, the planet being well defined, the shadow of III satellite was traversing the polar regions of *Jupiter* in high north latitude, and appeared very large and distinct; slightly but sensibly oval.
163 Tangential and well defined in glimpses.
164 Limb sensibly broken.
167 Limb still indented.
168 Last seen; limb complete; considered very good throughout this phenomenon.
169, 170, 171 Good; very steady and well defined throughout.

Ref. No.

172 Steady and well defined, but at times a boiling motion on limb; well on when first seen.
173 to 179 Steady and well defined, but at times a boiling motion on limb.
174 Good.
176 Good; satellite faint, lying on a bright cloud belt.
177 A little late.
179 Good observation.
180 Very good; first seen as a minute speck of light.
183, 184, 185 Unsteady, limb boiling.
186 Very good; first seen as a minute speck of light.

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Reference No.	Observer.	Day of Observation.	Satellites.	Phenomenon.	Phase of Phenomenon.	Adelaide Mean Time.	Corresponding Greenwich Mean Time.	Greenwich Mean Time by *Nautical Almanac.*	Apparent Error of *Nautical Almanac.*	Power.
		1876				h m s	h m s	h m s	m s	
188	T	Sept. 20	I	Oc. D.	External contact	8 40 14·00	23 25 52·70			125
189	„	„ „	„	„	Bisection (?)	8 41 41·00	23 27 19·70	23 29		„
190	„	„ „	„	„	Disappearance	8 43 55·00	23 29 33·70			„
191	R	„ 22	I	Ec. R.	First seen	6 28 33·97	21 14 12·67			200
192	„	„ „	„	„	Quite distinct	6 29 8·97	21 14 47·67	21 14 37·3	+0 24·63	„
193	„	„ „	„	„	Full blaze (?)	6 30 33·97	21 16 12·67			„
194	T	„ „	II	Ec. R.	First seen	9 45 30·55	0 31 9·25			125
195	„	„ „	„	„	Quite distinct	9 46 51·55	0 32 30·25	0 33 18·7	+2 9·45	„
196	„	„ „	„	„	Full blaze (?)	9 50 8·55	0 35 47·25			„
197	T	„ 24	III	Oc. R.	External contact	6 16 31·92	21 2 10·62	21 2		200
198	T	„ „	III	Ec. D.	Disappearance	8 32 50·02	23 18 28·72	23 13 51·1	−4 37·62	125
199	T	Oct. 7	I	Tr. E.	Internal contact	6 39 54·70	21 25 33·40			200
200	„	„ „	„	„	Bisection (?)	6 41 35·20	21 27 13·90	21 30		„
201	„	„ „	„	„	External contact	6 43 24·20	21 29 2·90			„
202	T	„ 8	II	Tr. E.	Internal contact	7 29 28·45	22 15 7·15			„
203	„	„ „	„	„	Bisection (?)	7 33 13·45	22 18 52·15	22 20		„
204	„	„ „	„	„	External contact	7 36 18·45	22 21 57·15			„
205	T	„ 14	I	Tr. I.	External contact	6 29 3·04	21 14 41·74			„
206	„	„ „	„	„	Bisection (?)	6 30 52·54	21 16 31·24	21 17		„
207	„	„ „	„	„	Internal contact	6 32 57·54	21 18 36·24			„

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208	T	„	„	I	Sh. I.	First seen	7 21 50·98	22 7 29·68	}	22 6			125
209	„	„	„	„	„	Internal contact	7 26 2·98	22 11 41·68	}				„
210	T	„	15	I	Ec. R.	First seen	6 41 6·36	21 26 45·06	}	21 27 8·6		+0 23·54	„
211	„	„	„	„	„	Full blaze (?)	6 44 7·36	21 30 46·06	}				„
212	T	„	„	II	Tr. I.	External contact	7 39 22·26	22 25 0·96	}				200
213	„	„	„	„	„	Bisection (?)	7 42 42·26	22 28 20·96	}	22 27			„
214	„	„	„	„	„	Internal contact	7 45 59·26	22 31 37·96	}				„

Remarks.

Ref. No.

188, 189, 190 } Badly defined; edges of planet woolly and ragged.

191 First seen as a minute speck of light; very faint; considered good.

192, 193 } Considered good.

194, 195, 196 } Good.

197 Too late for first appearance.

198 Very exact.

199, 200, 201 } Very good; fairly steady.

Ref. No.

202, 203, 204 } Considered good; planet well defined, but limb rather unsteady.

205, 206, 207 } Very good.

208, 209 } Both worthless; limb too unsteady and ill defined.

210, 211 } Wonderfully beautiful view of planet; splendidly defined.

211 As bright as No. II close by, the two making a pretty double star.

212, 213, 214 } Good, but not so well defined as at the previous observation.

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Notes on Physical Appearance of Planet, 1876.

June 28, 8.30 P.M.—From about 10° north latitude to about 20° to 25° south latitude the planet was of a bright salmon colour, varied by streaks and patches of cumulus-looking clouds, more especially in the southern portion. Over each temperate zone there was a very decided belt of bright cumulus cloud, between which and the poles the surface was of a greyish green or olive green colour, mottled with streaks and patches of cloud. The outlines of the bright cloud belts were very marked and well defined.—R.

July 30, 6.35.—On either side of the equator, reaching to latitude 15° ±, the planet was of a pale salmon colour, mottled with small detached cumulus or cirro-cumulus looking clouds and narrow white parallel streaks. The southern margin of this band was bounded by a long bank of cumulus cloud, reaching diagonally from latitude 15° or 20° on east limb to latitude 35° ± on west limb, dividing into two branches on west side of the planet's polar diameter. From the poles to about latitude 60° the planet was of a dull greyish green, varied with a few bright belts.—T.

August 29, 7.30.—From about 15° north latitude to 15° south latitude the planet was of a salmon colour, over the southern half of which were scattered clouds, between which the salmon coloured ground was visible. Between latitude 15° and 25° north there was a very bright belt of cloud, having its northern edge very marked and well defined. Between this and the north pole there were less brilliant cloud belts, overlying a greyish green ground. Scattered clouds around pole.

The scattered clouds south of the equator had a remarkable dark band, which seemed to be a rift in the clouds, south of which the clouds had a dull appearance. In the temperate regions of the southern hemisphere, as also in the northern, there was the greyish green colour seen between scattered clouds; and round the south pole was of a light greyish colour.

During this observation it was particularly remarked that in the northern hemisphere the north edge of belts and clouds was the most marked and well defined, which also applied to the south sides of same in the southern hemisphere.—R.

Oct. 15, 6.42.—Wonderfully beautiful view of planet, definition splendid. Over the equatoreal regions, for a space of about 15° or 20° on either side of the equator, were delicate streaks of cloud, some being knotted like small cumulus or cirro-cumulus resting on a background of a deep salmon tint. Towards the south a bank cumulus, having its horizontal base towards the equator, reached across the planet. This bright band, which had the roundish outline of cumulus, reached nearer to the south pole than usual, or to within about 40° of the pole, varied by dark spaces here and there. The north pole was of the usual greyish green tint, bounded by a broad bright band over the temperate or middle zone.—T.

The Observatory, Adelaide,
1876, *November* 30.

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Ephemeris for Physical Observations of Mars, 1877.

By Mr. A. Marth.

Greenwich Noon. 1877.	Angle of Position of ♂'s Axis.	Areographical Western Long. of the Centre of ♂'s Disk.	Diff.	Areographical Latitude of ♂'s Disk.	Diameter.	Amount of Greatest Defect of Illumination.	Position of Greatest Defect of Illumination.	Areocentric Angle between Earth and Sun.
	°	°	°	°	″	″	°	°
June 9	348·55	269·77		−24·19	12·76	1·72	249·91	43·09
			700·70					
11	347·85	250·47		24·27	13·00	1·74	249·80	42·91
			·71					
13	347·17	231·18		24·33	13·24	1·75	249·72	42·70
			·73					
15	346·50	211·91		24·38	13·49	1·77	249·65	42·47
			·76					
17	345·85	192 67		24·41	13·74	1·78	249·59	42·22
			·77					
19	345·22	173·44		24·44	14·00	1·79	249·55	41·94
			·80					
21	344·60	154·24		24·45	14·27	1·80	249·53	41·64
			·82					
23	344·00	135·06		24·45	14·54	1·81	249·52	41·31
			·84					
25	343·42	115·90		24·44	14·82	1·81	249·53	40·96
			·88					
27	342·87	96·78		24·42	15·11	1·82	249·55	40·58
			·90					
29	342·33	77·68		24·39	15·40	1·82	249·59	40·17
			·93					
July 1	341·81	58·61		−24·35	15·70	1·81	249·65	39·74
			700·97					
3	341·32	39·58		24·30	16·01	1·81	249·73	39·27
			701·00					
5	340·85	20·58		24·24	16·33	1·80	249·83	38·77
			·04					
7	340·41	1·62		24·18	16·65	1·78	249·95	38·23
			·07					
9	339·99	342·69		24·11	16·97	1·77	250·08	37·65
			·12					
11	339·60	323·81		24·03	17·31	1·75	250·24	37·04
			·16					
13	339·23	304·97		23·95	17·65	1·72	250·42	36·39
			·20					
15	338·89	286·17		23·68	17·99	1·69	250·63	35·69
			·25					
17	338·57	267·42		23·77	18·34	1·65	250·86	34·96
			·30					
19	338·29	248·72		23·68	18·69	1·61	251·12	34·18
			·34					
21	338·03	230·06		23·58	19·05	1·57	251·40	33·36
			·40					
23	337·80	211·46		23·49	19·41	1·52	251·72	32·49
			·44					
25	337·60	192·90		23·39	19·77	1·46	252·08	31·57
			·50					

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Greenwich Noon. 1877.	Angle of Position of ♂'s Axis.	Areographical Western Long. of the Centre of ♂'s Disk.	Diff.	Latitude	Diameter.	Amount and Position of Greatest Defect of Illumination.		Areocentric Angle between Earth and Sun.
	°	°	°	°	"	"	°	°
July 27	337·43	174·40		−23·29	20·14	1·40	252·47	30·61
			·55					
29	337·29	155·95		23·19	20·50	1·34	252·90	29·60
			·61					
31	337·18	137·56		23·10	20·87	1·27	253·38	28·54
			·66					
Aug. 2	337·10	119·22		−23·01	21·23	1·19	253·92	27·42
			701·73					
4	337·05	100·95		22·92	21·58	1·11	254·52	26·25
			·78					
6	337·04	82·73		22·84	21·93	1·03	255·19	25·03
			·84					
8	337·06	64·57		22·76	22·27	0·94	255·95	23·76
			·90					
10	337·11	46·47		22·70	22·60	0·86	256·79	22·44
			701·96					
12	337·19	28·43		22·63	22·91	0·77	257·77	21·06
			702·01					
14	337·30	0·44		22·58	23·21	0·68	258·92	19·64
			·06					
16	337·44	352·50		22·52	23·49	0·59	260·25	18·18
			·10					
18	337·61	334·62		22·48	23·75	0·50	261·82	16·68
			·16					
20	337·81	316·78		22·44	23·98	0·42	263·70	15·15
			·21					
22	338·04	298·99		22·42	24·19	0·34	266·01	13·60
			·24					
24	338·29	281·23		22·40	24·37	0·27	268·92	12·03
			·28					
26	338·56	263·51		22·39	24·52	0·21	272·70	10·46
			·32					
28	338·85	245·83		22·40	24·63	0·15	277·78	8·92
			·34					
30	339·16	223·17		22·41	24·71	0·10	284·9	7·45
			·35					
Sept. 1	339·48	210·52		−22·43	24·76	0·07	295·2	6·13
			702·37					
3	339·81	192·89		22·46	24·76	0·05	310·5	5·08
			·38					
5	340·15	175·27		22·49	24·73	0·04	331·4	4·52
			·37					
7	340·50	157·64		22·54	24·66	0·04	354·2	4·64
			·37					
9	340·84	140·01		22·60	24·56	0·05	13·2	5·39
			·35					
11	341·17	122·36		22·67	24·41	0·08	26·5	6·55
			·33					
13	341·50	104·69		22·74	24·23	0·12	35·5	7·92
			·30					
15	341·81	86·99		22·83	24·02	0·16	41·80	9·39
			·27					
17	342·10	69·26		22·92	23·78	0·21	46·33	10·91
			·23					

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Greenwich Noon. 1877.	Angle of Position of ♂'s Axis.	Areographical Western Long. of the Centre of ♂'s Disk.	Diff.	Latitude	Diameter.	Amount of Greatest Defect of Illumination.	Position	Areocentric Angle between Earth and Sun.
	°	°	°	°	″	″	°	°
Sept. 19	342·38	51·49		−23·02	23·52	0·27	49·74	12·44
			·19					
21	342·63	33·68		23·13	23·22	0·34	52·39	13·97
			·14					
23	342·86	15·82		23·25	22·91	0·41	54·51	15·46
			·10					
25	343·06	357·92		23·38	22·57	0·49	56·23	16·93
			702·04					
27	343·23	339 96		23·51	22·22	0·57	57·67	18·37
			701·98					
29	343·37	321·94		23·65	21·85	0·64	58·87	19·76
			·93					
Oct. 1	343·47	303·87		−23·80	21·47	0·72	59·90	21·10
			701·88					
3	343·54	285·75		23·95	21·09	0·80	60·78	22·40
			·82					
5	343·58	267·57		24·11	20·69	0·87	61·54	23·65
			·75					
7	343·59	249·32		24·27	20·29	0·94	62·20	24·84
			·70					
9	343 56	231·02		24·44	19·89	1·01	62·78	25·98
			·64					
11	343·49	212·66		24·61	19·49	1·07	63·28	27·07
			·58					
13	343·39	194·24		24·78	19·09	1·13	63·72	28·11
			·52					
15	343·26	175·76		24·96	18 69	1·18	64·11	29·10
			·47					
17	343·10	157·23		25·14	18·29	1·23	64·44	30·03
			·41					
19	342·90	138·64		25·32	17·90	1·27	64·74	30·92
			·36					
21	342·67	120·00		25·50	17·52	1·31	64·99	31·76
			·31					
23	342·41	101·31		25·68	17·14	1·35	65·21	32·56
			·26					
25	342·13	82·57		25·85	16·77	1·38	65·41	33·31
			·21					
27	341·82	63·78		26·03	16·40	1·40	65·57	34·01
			·17					
29	341·49	44·95		26·20	16·04	1·42	65·72	34·68
			·12					
31	341 13	26·07		26·37	15·69	1·44	65·84	35·31
			·08					
Nov. 2	340·74	7·15		−26·53	15·35	1·46	65·94	35·89
			701·04					
4	340·34	348·19		26·69	15·02	1·47	66·03	36·44
			700·99					
6	339·92	329·18		26·84	14·70	1·48	66·10	36·96
			·96					
8	339·47	310·14		26·99	14·38	1·48	66·16	37·44
			·92					
10	339·01	291·06		27·12	14·07	1·48	66·21	37·88
			·89					

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Greenwich Noon. 1877.	Angle of Position of ♂'s Axis.	Areographical Western Long. of the Centre of ♂'s Disk.	Diff.	Latitude	Diameter.	Amount and Position of Greatest Defect of Illumination.		Areocentric Angle between Earth and Sun.
	°	°		°	″	″	°	°
Nov. 12	338·53	271·95		−27·25	13·77	1·48	66·25	38·29
			·86					
14	338·04	252·81		27·37	13·48	1·48	66·28	38·68
			·82					
16	337·54	233·63		27·49	13·20	1·47	66·31	39·03
			·79					
18	337·02	214·42		27·59	12·92	1·47	66·33	39·35
			·76					
20	336·49	195·18		27·68	12·66	1·46	66·35	39·65
			·74					
22	335·95	175·92		27·76	12·40	1·45	66·36	39·93
			·71					
24	335·40	156·63		27·84	12·14	1·43	66·37	40·18
			·69					
26	334·85	137·32		27·89	11·90	1·42	66·38	40·41
			·67					
28	334·29	117·99		27·94	11·66	1·40	66·39	40·61
			·64					
30	333·73	98·63		27·98	11·43	1·39	66·40	40·79
			·62					
Dec. 2	333·16	79·25		−28·00	11·21	1·37	66·41	40·96
			700·61					
4	332·59	59·86		28·01	10·99	1·35	66·42	41·10
			·59					
6	332·02	40·45		28·00	10·78	1·34	66·43	41·22
			·57					
8	331·45	21·02		27·98	10·58	1·32	66·45	41·33
			·55					
10	330·88	1·57		27·95	10·38	1·30	66·47	41·41
			·54					
12	330·32	342·11		27·91	10·18	1·28	66·49	41·48
			700·54					
14	329·75	322·65		−27·85	10·00	1·26	66·52	41·54

1877	April 24	Autumnal Equinox of *Mars*' northern hemisphere.			
1877	Sept. 18	Winter Solstice	,,	,,	,,
1878	Feb. 22	Spring Equinox	,,	,,	,,

The following list gives the areographic longitude and latitude of the centre of the disk of *Mars*, and also its apparent diameter, for the times of a number of sketches made during the oppositions of 1862 and 1864. Not to make it too lengthy, it is confined to the sketches of—

Dawes (8 sketches in vol. 25 of the *Monthly Notices*, p. 225).
Von Franzenau (6 in vol. 51 of the *Sitzungsberichte* of the Vienna Academy, p. 509).
Harkness (2 in the Washington Observations of 1862, p. 152).
Kaiser (2 plates with respectively 9 and 12 sketches in vol. 3 of the *Annalen der Sternwarte in Leiden*).
Lassell (2 plates with 24 sketches in vol. 32 of the *Memoirs of the Royal Astronomical Society*).
Lockyer (4 plates with 16 sketches in the same volume).
Rosse (6 sketches made at Lord Rosse's Observatory, published in the same volume).
Secchi (8 sketches made by Secchi or Cappelletti, and published in Tav. V. p. 76 of *Memorie del Osservatorio d. Coll. Rom. Nuova Serie. Roma*, 1863).

The sketches are arranged in the order of the longitudes of their central meridians.

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Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Time assigned to the Sketches.		
°	°	"				
1·1	−21·2	22·8	Lassell 3	1862 Sept. 22·44		Gr.
5·7	−25·2	19·8	„ 16	Oct. 27·31		„
6·5	− 2·2	17·0	Franzenau 2	64 Nov. 10 9h 30m		Vienna.
12·1	−22·1	23·0	Harkness 2	62 Sept. 30 11h		Washgt.
12·1	−21·3	22·9	Lockyer I. 2	23 11h 55m		Gr.
18·8	−21·0	22·7	Lassell 2	20·44		„
19·7	−25·0	20·2	Secchi 4	Oct. 25 8h		Rome.
23·8	− 2·4	17·0	Kaiser II. 2	64 Nov. 11 10h 30m		Leiden.
24·0	− 3·0	17·2	Dawes 10	14 12h 0m		Gr.
24·3	− 1·9	16·8	Franzenau I.	8 9h 30m		Vienna.
26·7	−21·3	22·9	Lockyer I. 3	62 Sept. 23 12h 55m		Gr.
28·2	− 2·1	16·9	Kaiser II. 1	64 Nov. 9 9h 35m		Leiden.
29·0	−25·1	20·0	Secchi 5	62 Oct. 26 9h 15m		Rome.
39·5	−25·3	19·5	Rosse 5	29 1h		Sid. T. Birr C.
45·0	−26·5	13·4	Kaiser I. 7	Dec. 2 8h 35m		Leiden.
48·2	−25·0	20·2	Lassell 15	Oct. 25·38		Gr.
49·1	− 2·6	17·1	Dawes 12	64 Nov. 12 12h 30m		„
49·4	−20·7	22·5	Lockyer I. 4	62 Sept. 17 10h 50m		„
49·8	− 9·7	15·7	Kaiser II. 7	64 Dec. 18 10h 0m		Leiden.
? 59	−20·7	22·5	Lockyer II. 1	62 Sept. 17 ?		
60·5	− 2·3	17·0	Dawes 13	64 Nov. 10 12h 6m		Gr.
69·2	−24·8	20·5	Lassell 14	62 Oct. 23·39		„
75·1	−10·1	11·2	Dawes 15	65 Jan. 21 8h		„
77·0	−24·6	20·9	Lassell 13	62 Oct. 25·36		„
80·8	−20·5	22·1	„ 1	Sept. 13·439		„
83·8	− 9·3	16·0	Kaiser II. 8	64 Dec. 15 10h 30m		Leiden.
85·3	−24·2	21·4	Secchi 3	62 Oct. 18 8h 13m		Rome.
86·2	−20·6	22·4	Rosse 3	Sept. 16 23h 55m		Sid. T. Birr C.
86·4	−24·9	20·4	Kaiser I. 3	Oct. 24 11h 25m		Leiden.
94·3	−24·2	21·4	Lockyer II. 2	Oct. 18 8h		Gr.
113·5	−20·5	22·2	Rosse 2	Sept. 14 0h 26 (assuming the time to be 0h 26m instead of 6h 26m)		Sid. T. Birr C.
118·8	−26·5	14·8	Kaiser I. 6	Nov. 23 7h 50m		Leiden.
119·8	−26·5	15·0	Lassell 22	22·29		Gr.
123·2	− 8·4	16·6	Kaiser II. 6	64 Dec. 10 10h 10m		Leiden.
127·5	− 1·2	16·4	Dawes 2	Nov. 3 12h 24m		Gr.
128·3	−24·2	21·4	Lassell 12	62 Oct. 18·43		„

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Areographical Long. of the Centre of the Disk. °	Areographical Lat. of the Centre of the Disk. °	Diameter. ″		Times assigned to the Sketches.	
137·2	−24·1	21·5	Lassell 11	17·43	Gr.
137·5	−23·9	21·8	Lockyer II. 3	15 9h 8m	,,
? 140·5	,,	,,	,, II. 4	past 9h 20m	,,
144·4	−23·9	,,	Lassell 10	15·40	,,
153·7	−26·4	15·7	,, 21	Nov. 18·28	,,
162·1	−23·7	22·0	,, 9	Oct. 13·40	,,
162·3	−26·5	15·5	Kaiser I. 5	Nov. 19 8h 15m	Leiden.
163·0	−26·4	15·8	Lassell 20	17·28	Gr.
168·1	−26·4	16·1	Secchi 8	16 7h 16m	Rome.
179·7	−23·4	22·3	Lassell 8	Oct. 11·40	Gr.
188·6	−26·3	16·3	,, 19	Nov. 15·30	,,
195·8	−23·4	22·3	Kaiser I. 2	Oct. 11 11h 0m	Leiden.
199·9	−10·8	12·9	,, II. 12	65 Jan. 7 8h 0m	,,
201·2	−23·4	22·3	Lockyer III. 1	62 Oct. 11 11h 4m	Gr.
214·7	−23·1	22·5	,, III. 2	9 10h 47m	,,
220·1	− 6·2	17·3	Kaiser II. 5	64 Nov. 29 10h 10m	Leiden.
221·4	−26·2	17·1	Secchi 7	62 Nov. 11, 7h 45m	Rome.
233·7	− 6·6	17·3	Dawes 4	64 Dec. 1 12h 0m	Gr.
236·4	−10·8	13·5	Kaiser II. 11	65 Jan. 3 8h 0m	Leiden.
238·1	−26·1	17·4	Secchi 6	62 Nov. 9 7h 38m	Rome.
240·2	−20·2	21·3	Harkness 1	Sept. 6 12h	Washgt.
248·7	− 4·2	17·4	Franzenau 4	64 Nov. 20 7h 30m	Vienna.
253·0	− 4·6	17·5	,, 6	22 9h 0m	,,
263·3	−22·4	22·9	Lockyer III. 3	62 Oct. 3 10h 30m	Gr.
264·1	−26·0	11·7	Kaiser I. 9	Dec. 14 6h 45m	Leiden.
271·8	−22·7	22·9	,, I. 1	Oct. 5 12h 35m	,,
274·3	− 5·6	17·4	Dawes 6	64 Nov. 26 11h 46m	Gr.
276·2	−22·4	22·9	Lockyer III. 4	62 Oct. 3 11h 23m	
278·0	−23·2	14·6	Rosse 1	July 22 22h 30m	Sid. T. Birr C.
280·4	− 4·2	17·4	Franzenau 5	64 Nov. 20 9h 40m	Vienna.
283·0	−22·4	22·9	Lockyer IV. 1	62 Oct. 3 11h 51m	Gr.
283·3	−22·8	22·7	Rosse 4	6 2h 10m	Sid. T. Birr C.
287·6	−25·9	18·1	Lassell 18	Nov. 5·32	Gr.
290·2	− 4·7	17·5	Kaiser II. 4	64 Nov. 22 10h 45m	Leiden.
290·8	−10·6	14·3	,, II. 10	Dec. 28 8h 0m	,,
295·9	−21·9	23·0	Lassell 7	62 Sept. 29·43	Gr.
296·7	−25·8	18·3	,, 17	Nov. 4·32	,,

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Areographical Long. and Lat. of the Centre of the Disk.		Diameter.		Times assigned to the Sketches.		
°	°	"				
300·2	−26·1	12·1	Lassell 24	Dec. 11·29		Gr.
301·8	−21·6	23·0	Secchi 2	Sept. 26	9h 45m	Rome.
320·5	−21·7	23·0	Lassell 6	27·45		Gr.
322·1	− 3·2	17·3	Franzenau 3	64 Nov. 15	9h 30m	Vienna.
324·2	−26·2	12·3	Kaiser I. 8	62 Dec. 10	8h 15m	Leiden.
324·6	− 4·2	17·4	Dawes 8	64 Nov. 20	11h 36m	Gr.
325·2	− 4·0	17·4	Kaiser II. 3	19	11h 20m	Leiden.
328·8	−26·3	12·5	Lassell 23	62 Dec. 8·29		Gr.
328·9	−25·9	17·9	Rosse 6	Nov. 6	1h 40m	Sid. T. Birr C.
332·4	−21·1	22·8	Secchi 1	Sept. 21	20h 50m	Sid. T. Rome.
334·5	−21·5	22·9	Lassell 5	25·44		Gr.
337·2	„	„	Lockyer IV. 2		10h 44m	Finished.
338·6	„	„	„ IV. 3		10h 50m	„
339·2	−21·3	22·9	„ IV. 4	23	9h 40m	„
343·4	−21·4	22·9	Lassell 4	24·44		„
344·4	−25·5	19·1	Kaiser I. 4	Oct. 31	8h 45m	Leiden.
350·2	−21·3	22·9	Lockyer I. 1	Sept. 23	10h 25m	Gr.
356·5	−10·2	15·0	Kaiser II. 9	1864 Dec. 23	9h 25m	Leiden.

On account of the uncertainty of the times assigned to the sketches, the longitudes of the central meridian may, of course, be considerably uncertain, an uncertainty of 1° of areographical longitude corresponding to about 4m·1 in time.

By interpolating the longitudes given in the Ephemeris for the times, when observations are to be taken, and consulting the corresponding sketches, trustworthy observers may properly prepare themselves for fixing their attention upon the most desirable observations which can then be made. Amongst the most important are careful observations of the times and places of the passages across the central meridian of all the most distinct and well defined points on the planet's surface, which may serve as fundamental points of Areography. Foremost amongst them are the point *f* (the neck of the hour-glass), the spot *a* (the end of the serpentine), and the centre of spot *d* (the pupil of the eye) of Mädler's map of 1830. Since, in observing, the diameter of the disk —which passes through the southern polar spot S—will have to be taken as the central meridian, the observations will require to be corrected, not only for phase, for which the Ephemeris supplies the necessary data, but also for the non-coincidence of S with the southern pole, for the determination of which series of carefully observed angles of position of S are required. It is to be hoped that astronomers who have the requisite instruments at their service will not let slip the opportunities of the approaching opposition for making substantial contributions towards our better knowledge of *Mars*.

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Note on the Results of Heliometer Observations of the Planet Juno, to determine its Diurnal Parallax.

By Lord Lindsay and Mr. David Gill.

The reduction of the observations made with the heliometer for determination of the diurnal parallax of *Juno* at Mauritius being finished, it may be of interest to present the final results to the Society in anticipation of the full details now in the press, forming vol. ii. of the Dun Echt publications.

Corrections of the tables of the planet were obtained, founded on the results of meridian observations at Greenwich and Washington, and a fine series of extrameridian observations made by Mr. Wilson at Cambridge, U.S. In this latter series the stars of comparison were determined by Mr. Rogers with the transit circle of the same observatory.

Two systems of corrections were so obtained, founded on somewhat different expressions, greater weight being given to the Cambridge observations in the second system.

The computations were made separately on both systems, with the following result:—

	1st system.	2nd system.
Mean ⊙ parallax	$8''\cdot77 \pm 0''\cdot041$	$8''\cdot76 \pm 0''\cdot042$

From the late arrival of the yacht at Mauritius, the observations could not be commenced until a week after opposition.

In consequence of this barely one-third of the anticipated number of observations could be secured, and these, in consequence, with small parallax factors, rendered still smaller by the fact that stars of comparison could not be obtained in the most favourable positions.

This being, so we do not present the result as a determination of the parallax possessing a high weight. There is a discordant value on November 15, which in a larger series would have probably counter-balanced by another, in which all the sources of error had combined in the opposite way; and thus, if we are asked what we believe to be the most probable value resulting from the determination, we should reject this result. The values then become

1st system.	2nd system.
$8''\cdot82$	$8''\cdot81$

and these we believe to be exceedingly close approximations to the true ⊙ parallax.

At the same time we are aware that the rejection of any observation is quite unsound; and we simply present these values, not as a determination of the parallax, but as the result of a first experiment, made under somewhat trying and difficult circumstances, from which conclusions can be drawn as to the future value of the method.

That which we desire now more particularly to bring before the Society is the following table, showing the residuals in the

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equations when the errors of the star places have been eliminated, and the first-mentioned values of π are substituted in them.

Each equation from which a residual results is the arithmetical mean of all the equations resulting from the comparisons in each epoch, so that the residuals show actually the errors of the observations in distance of each evening and morning.

A reference to the map of the path of *Juno*, published in connection with our paper in vol. xxxiv. p. 279 of the *Monthly Notices* of the Society, will show the stars of comparison referred to.

		Star of Comparison.	1st system.	2nd system.
			"	"
Nov. 12	Evening	θ	+0·088	+0·103
	Morning	θ	+0·129	+0·134
13	Evening	θ	−0·038	−0·034
	Morning	θ	−0·084	−0·094
15	Evening	ζ	−0·074	−0·075
	,,	λ	+0·114	+0·113
	Morning	ζ	+0·206	+0·199
	,,	λ	−0·213	−0·206
18	Morning	θ	−0·003	−0·001
	,,	μ	+0·012	+0·023
19	Evening	θ	+0·021	+0·024
	,,	μ	−0·016	−0·020
23	Evening	ι	+0·075	+0·053
	,,	χ	−0·080	−0·060
24	Morning	ι	−0·102	−0·069
	,,	χ	+0·101	+0·073
25	Evening	μ	−0·081	−0·134
	Morning	μ	−0·004	−0·042
26	Evening	μ	−0·153	−0·176
	Morning	μ	−0·051	−0·073
29	Morning	ν	−0·019	−0·180
30	Evening	ν	−0·194	−0·259

The resulting probable error of a complete comparison deduced from this table is $\pm$ 0″·075, confirming beyond all doubt the conclusion at which we arrived in the paper referred to, viz:

> *That by means of the Heliometer it is possible to determine the distance of a minor planet from a single star near it, or to interpolate its place relative to two distant stars, with a probable error less than* $\frac{1}{10}$ *th of a second of arc.*

A *near* star is one whose distance is less than 1000″ from the planet.

A *distant* star, from 1000″ to 7000″.

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On the proposed Expedition to observe the approaching Opposition of Mars. By Mr. David Gill.

The approaching opposition of *Mars* is the most favourable of the century for determining the Solar Parallax, the horizontal parallax at opposition being within 5 per cent. of the difference of the horizontal parallax of the Sun and *Venus* at the Transit of 1874.

During six weeks observations can be made in conditions of temperature and of freedom from hurry or excitement infinitely more favourable to good observations than those afforded by the Transit of *Venus*. By observing the diurnal parallax, the same observer gets a result which is entirely free from errors of personality, and he also obtains a factor of parallax larger than can be obtained by any two existing observatories.

So early as 1857 the Astronomer Royal called attention to the present opposition, and then expressed his opinion—an opinion to which he still adheres—that observations of the diurnal parallax of the planet at such an opposition present the best means of determining the Solar Parallax.

The method proposed by the Astronomer Royal was to observe the difference of R.A. of the planet and stars in the evening and morning, and by such a method, with a proper equatoreal and a skilful observer, there is no doubt that results of very high accuracy could be attained. The success which has attended the observations of *Juno* (the results of which are communicated to the Society to-night) led me to believe that the original plan of the Astronomer Royal might be somewhat modified, and the heliometer successfully substituted for the ordinary equatoreal, according to a plan of observation afterwards described.

I applied in the first place to Lord Lindsay, who, in the kindest manner and with the most complete sympathy with the purposes in view, at once placed the instrument at my disposal.

I then submitted detailed plans of the proposed observations to the Astronomer Royal, to the Council of this Society, to Prof. Adams, and to Dr. Robinson and Mr. Hind, and I gratefully acknowledge the support in the matter which I have received at their hands, as also the promises of substantial assistance, should it be required, which I have received from Sir George Airy, Mr. De La Rue, Mr. Proctor, and others. I have also consulted Dr. Auwers of Berlin as to several details of these plans, and have now, as at all times, received from him the kindest and most valuable assistance. I now beg to present to the Society the following plan of the proposed observations:—

Selection of Place of Observation.

In heliometer observations distances are measured with much greater accuracy than position-angles, therefore we should endeavour to select stars nearly vertically above or below the

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planet if we wish to have the full amount of parallactic displacement most advantageously measured. The star which is vertically above or below the planet in the evening observations (neglecting the planet's motion) can only be vertically above or below the planet in the morning in one case, and that is when the observer's station is on the equator and the star's and planet's declination are both 0°.

When the planet has any other declination, we must endeavour to select a station in which the planet is on the prime vertical at the mean altitude of observation (found practically to be 30°), and to select the stars of comparison of the same declination with the planet. The observations evening and morning are then symmetrically disposed as to parallactic displacement. In the case of *Mars* at the present opposition this condition is realised in a latitude about 8° S.

The meteorological conditions are also, of course, all-important, and it has been suggested to me that I should occupy some rainless district in the highlands of Peru, affording almost the certainty of clear weather every night. There appears to be a very serious drawback, however, in the great difference of temperature between day and night. It is no uncommon thing, in the higher districts there, to have a temperature verging on 100° Fahr. by day and freezing by night, and I feared, however perfectly and symmetrically the comparison stars and observations may be arranged for the elimination of progressive change of scale-value, that errors due to temperature may yet creep in which might have a systematic character.

In this respect insular stations have a great advantage, and after much consideration I have selected the Island of Ascension—originally suggested to me by Lieut. Neate, R.N.—as the most suitable site. Its geographical position is almost absolutely the best possible, and to Mr. Scott and Captain Toynbee I am indebted for a copy of a work, just issued by the Meteorological Office, on the meteorology of this island.

The proportion of cloud is from 5·0 to 6·0 (10 being total obscuration) for the date and hours of observation, a proportion smaller than Mauritius, where the conditions were sufficiently favourable. Two or three degrees appear to be the range of temperature between 6 P.M. and 6 A.M.

Selection of Stars of Comparison.

In making this selection, a complete list was independently prepared of all the stars of 8th magnitude or brighter near the path of *Mars* contained in the following catalogues:—

Catalogue of the Berlin Academy Star Maps.

Weisse's Bessel.

Lalande.

Santini.

Lacaille.

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These were all independently reduced to 1877·0 and plotted on a chart, together with the path of the planet. It proved that several very important stars were omitted in Bessel's Catalogue; the reason, I believe, being, that when that Astronomer found two stars in the field and could not observe both, he always chose the fainter star, leaving the larger star to other observers, as less likely to be overlooked by them.

Such an omission is the star marked *g* (7½ mag.) in the catalogue, which is very important, because on September 5 the planet approaches within 2′ of this star.

In the selection of the stars of comparison, I have been guided by the following considerations:—

1. It is desirable, if possible, and if consistent with the main end in view—the parallax determination—to make the most accurate determination possible of the absolute place of the planet for the purposes of gravitational astronomy.
2. Position-angle measures being greatly inferior to measures of distance in point of accuracy, the determination of absolute positions will be best secured by relying on the distance measures only.
3. The minimum number of stars by which an absolute place can be secured by distance measures is three, and it is not desirable to measure more, because to measure from three stars symmetrically will require nearly all the time which the measures should occupy.
4. The planet *must* be contained within the triangle formed by the three stars of comparison; and, since the change in R.A. is the most important, two of the stars should be about the same declination with the planet, and as nearly as possible equally distant from it. When this is not possible, the stars must be arranged to determine rigidly the displacement in R.A., sacrificing, if necessary, the declination.
5. When stars can be found sufficiently bright, and nearly of the same declination with the planet, not more than 2000″ or 3000″ apart, then the method of two stars, employing position-angles, is best if the planet is nearly in the line joining the stars of comparison.

In the equations of condition which result from measures of distance with stars so selected, it is always possible to consider the error of the scale-value an unknown quantity, and to determine it from the stars of comparison in each group of observations. This is the best method for complete elimination of systematic error when the places of the stars of comparison are determined with tolerable precision.

To secure such precision, as well for this purpose as for the determination of the absolute place of the planet, the places of the stars of comparison must be determined by meridian observations; and to increase the precision of the result, the whole of

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the stars should be connected by a heliometric triangulation. To effect this it has been necessary to introduce a few additional stars, in general denoted by Greek letters.

I have also included in the list the star ψ^1 *Aquarii*, because peculiar interest attaches to it from the fact that it was occulted by *Mars* in 1672, October 1. The occultation was observed by Richer at Cayenne, by Picard near Beauford, and by Roemer at Paris, and the observations are in very close accordance (Le Verrier, *Comptes Rendus*, 1872, July 22). In this paper, M. Le Verrier deduces the Earth's mass, and thence the solar parallax, from the secular variation of the planet's longitude produced in two centuries by the action of the Earth, employing the occultation just cited with Bradly's observations of the star, on the one hand, and modern meridian determinations on the other.

The present opportunity for making a rigid determination of the planet's heliocentric place is infinitely more favourable than that of 1672, because the determination can be made to depend upon so many stars. There is no doubt that, if many observations of the stars of comparison and of fundamental stars are made at different observatories and with different meridian circles, and the heliometer observations have even moderate success, a determination of the heliocentric place of the planet will be secured of far higher accuracy than any hitherto obtained.

I therefore most earnestly solicit the co-operation of observatories possessing good meridian instruments in this work, and shall gratefully acknowledge and utilise any such observations communicated to me, addressed to the Rooms of the Society.

Mr. Hartnup, at Liverpool, has most kindly volunteered to apply the splendidly rigid Equatoreal of his Observatory to the determination of the differences of R.A. and declination of these stars of comparison. These observations will chiefly strengthen the heliometric triangulation, but do not supersede the desirability, or even necessity, for good meridian observations also.

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Stars to be observed with Mars at Opposition 1877.

Adopted Name of Star.	Approximate. 1877·0 R.A. h m s	Dec. ° ′	No. in Weisse's Bessel.	Mag.	Mag. in Berlin Academy Star Cat.	No. in Lalande.	Mag.	No. in Santini.	Mag.	Remarks.
a	22 47 0	−12 16	xxii. 956	7	6	44756	6	2577 (1858)	7	
b	22 47 38	−12 50	966	7–8	7–8	...	8	2140 (1862)	7–8	
a	22 51 37	−11 47	1047	9						
c	22 53 7	−13 44	1079	6	7	44937	6½	2145 (1862)	6–7	
β	22 56 4	−11 55	1156	8	8	45050	8	2591 (1858)	8–9	Lalande has Dec. −10° 55′.
μ	22 58 3	−12 50	1204	8	8	...	...	2154 (1862)	8	Schj. $22^h\ 58^m\ 2^s{\cdot}91$ $-12°\ 50'\ 26''{\cdot}8$ (8–7)
d	22 59 28	−11 6	1232	8	7–8	45169	7	2594 (1858)	8	
γ	23 0 30	−13 23	1249	8	8–9	45197	9			
e	23 0 58	−12 28	1261	8	8	45213	8	2599 (1858)	7–8	
δ	23 5 3	−11 10	xxiii. 49	9						
e	23 5 32	−12 36	57	8	8	45380	7			
f	23 8 16	−11 21	123	7	7	45490	6			
g	23 8 55	−12 14	...	...	7–8	45504	7½			
ψ^1 Aq.	23 9 27	− 9 45	...	4–5						

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h	23 11 15	−12 23	xxiii. 185	7	7	45582	6	2618 (1858)	7	
i	23 12 34	−10 17	226	5–6	5	45628	6	2622 (1858)	5–6	ψ^3 Aquarii.
k	23 12 37	−12 51	228	8	8	45633	7	2177 (1862)	7	
l	23 14 29	−11 12	265	8	8	45708	8	2625 (1858)	8	
λ	23 16 36	−11 27	309	8	8–9	45777	8	2627 (1858)	8	
ζ	23 16 55	−10 4	315	8	8	45789	8	...	...	Schj. $23^h\ 16^m\ 54^s{\cdot}26$ $-10°\ 3'\ 33''{\cdot}1$ (8–7)
η	23 20 14	−1043	377	9						
m	23 21 40	−12 7	402	7	7	45937	6	2634 (1858)	7	
n	23 22 39	− 9 57	427	7	7	45965	6½	2636 (1858)	7	
q	23 26 4	−11 41	497	7	7	46090	6½	2643 (1858)	7	
r	23 29 6	−11 14	571	8	8	...	...	2653 (1858)	8	
s	23 29 40	− 9 27	586	7–8	7–8	46229	7½	...	...	Schj. $23^h\ 29^m\ 39^s{\cdot}37$ $-9°\ 26'\ 40''{\cdot}7$ (8)
	23 31 52	− 9 19	629	7	7	46296	7½			

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Plan of Heliometric Triangulation of Stars to be compared with Mars.

Stars.	Mag.	R.A. h m s	Dec. ° ′	Position Angle. °	Distance. ′
a—*b*	6-7—7-8	22 47 19	−12 33	344·9	35
a—*a*	6-7—9	49 19	12 2	246·8	74
b—*a*	7-8—9	49 37	12 19	222·9	86
b—*c*	7-8—6-7	50 22	13 17	303·9	97
c—*a*	6-7—9	52 22	12 46	164·1	119
c—*β*	6-7—8	54 37	12 50	201·6	117
c—*γ*	6-7—8	56 47	13 34	259·0	110
a—*β*	9—8	53 51	11 51	277·0	66
β—*d*	8—7-8	57 46	11 31	225·6	70
β—*e*	8—8	58 31	12 12	294·7	79
β—*γ*	8—8	22 58 17	12 39	323·6	109
d—*δ*	7-8—9	23 2 16	11 8	272·8	82
d—*e*	7-8—8	0 13	11 47	344·9	85
γ—*e*	8—8	0 44	12 56	187·1	55
γ—*ε*	8—8	3 1	13 0	237·4	87
e—*δ*	8—9	3 1	11 49	217·6	98
e—*ε*	8—8	3 15	12 32	276·8	67
δ—ψ^1 Aq.	9—4-5	7 15	10 28	217·4	107
δ—*f*	9—6-7	6 40	11 16	283·1	49
δ—*g*	9—7-8	6 59	11 42	318·4	86
δ—*h*	9—6-7	8 9	11 47	308·7	117
δ—*ε*	9—8	5 18	11 53	355·3	86
ε—*f*	8—6-7	6 54	11 59	208·1	85
ε—*g*	8—7-8	7 14	12 25	246·1	54
ε—*h*	8—7	8 24	12 30	261·2	85
ε—*k*	8—7-8	9 5	12 44	278·2	105
f—ψ^1 Aq.	6-7—4-5	8 52	10 33	190·3	98
f—*g*	6-7—7-8	8 36	11 48	349·7	54
f—*h*	6-7—7	9 46	11 52	324·7	76
f—*i*	6-7—5-6	10 25	10 49	224·8	90
f—*l*	6-7—8	11 23	11 17	264·4	92
f—*k*	6-7—7-8	10 27	12 6	324·7	110
g—*e*	7-8—8	4 57	12 21	83·2	117
g—*h*	7-8—7	10 5	12 19	284·8	35
g—*k*	7-8—7-8	10 46	12 33	304·4	66
g—*l*	7-8—8	11 42	11 43	232·9	103
ψ^1 Aq.—*ζ*	4-5—8	13 11	9 55	279·8	112

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Stars.	Mag.	R.A. h m s	Dec. ° ′	Position Angle. °	Distance. ″
ψ^1 Aq.—*i*	4-5—5-6	23 11 1	−10 1	304·7	56
ψ^1 Aq.—*l*	4-5—8	11 58	10 29	319·5	114
h—*l*	6-7—8	12 52	11 48	213·8	85
h—*k*	6-7—7-8	11 56	12 37	324·5	34
i—ζ	5-6—8	14 45	10 11	258·6	66
i—*l*	5-6—8	13 32	10 45	332·8	62
k—*l*	7-8—8	13 33	12 2	195·5	103
l—ζ	8—8	15 42	10 38	207·8	77
l—η	8—9	17 22	10 58	251·1	90
l—*m*	8—6-7	18 5	11 40	297·5	119
ζ—*n*	8—6-7	19 47	10 1	265·3	85
ζ—η	8—9	18 35	10 24	308·5	63
η—*q*	9—7	23 9	11 12	304·4	104
η—*m*	9—6-7	20 57	11 25	345·9	87
η—*n*	9—6-7	21 27	10 20	217·8	58
m—*q*	6-7—7	23 52	11 54	248·1	70
n—*q*	6-7—7	24 22	10 49	334·2	116
n—*r*	6-7—8	25 56	10 36	309·0	122
n—*s*	6-7—7-8	26 10	9 42	253·9	108
q—*r*	7—8	27 35	11 28	238·8	52
r—*s*	8—7-8	29 23	10 21	184·5	107
s—*t*	7-8—7	30 46	9 23	256·2	33
λ—*h*	8—6-7	13 56	11 55	54·4	96
λ—*i*	8—5-6	14 35	10 52	139·6	92
λ—*k*	8—7-8	14 37	12 9	34·9	102
λ—*l*	8—8	15 33	11 20	115·5	35
λ—*m*	8—6-7	19 8	11 47	298·2	85
λ—η	8—9	18 25	11 5	230·5	69
λ—ζ	8—9	23 16 46	10 46	183·3	83
μ—α	8—9	22 54 49	12 19	123·9	113
μ—β	8—8	57 3	12 23	152·5	62
μ—*c*	8—6-7	55 34	13 17	52·8	89
μ—γ	8—8	59 16	13 7	312·2	49
μ—*d*	8—7-8	58 45	11 58	191·6	106
μ—*e*	8—8	22 59 30	12 39	243·0	48
μ—*e*	8—8	23 1 47	12 43	262·8	111

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Plan of Observation of Mars and Comparison Stars.

[P denotes the planet; other letters the stars in the preceding list.]

Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point.	Dec. of Middle Point.	Position Angle.	Distance.	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point.	Dec. of Middle Point.	Position Angle.	Distance.
			h m s	° ′	°	′	h m s	° ′	°	′
Aug. 1	P—*q*	7-8	23 26 58	−10 44	13·0	117	23 27 1	−10 44	13·8	116
	P—*n*	7	25 15	9 52	82·6	77	25 18	9 52	83·5	79
	P—*t*	7	29 52	9 33	244·8	66	29 55	9 33	243·4	65
2	P—*q*	7-8	27 5	10 45	15·0	116	27 8	10 45	15·7	116
	P—*n*	7	25 22	9 53	84·3	81	25 25	9 53	84·4	82
	P—*t*	7	29 59	9 34	241·7	63	30 2	9 34	241·0	62
3	P—*q*	7-8	27 12	10 46	16·7	116	27 13	10 46	17·0	115
	P—*n*	7	25 29	9 54	85·2	84	25 30	9 54	85·9	84
	P—*t*	7	30 6	9 35	239·5	61	30 7	9 35	238·4	61
4	P—*q*	7-8	27 16	10 47	17·9	114	27 17	10 47	18·3	114
	P—*n*	7	25 33	9 55	86·7	87	25 34	9 55	87·4	88
	P—*t*	7	30 10	9 36	236·9	60	30 11	9 36	235·7	60
5	P—*q*	7-8	27 19	10 48	18·9	113	27 19	10 48	19·2	112
	P—*n*	7	25 36	9 56	88·0	88	25 36	9 56	88·7	88
	P—*t*	7	30 11	9 37	234·5	60	30 11	9 37	233·6	61
6	P—*q*	7-8	27 20	10 49	19·6	111	27 20	10 49	19·7	110
	P—*n*	7	25 37	9 57	90·0	89	25 37	9 57	90·0	89
	P—*t*	7	30 12	9 38	232·4	61	30 12	9 38	231·8	61

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7	P—q	7-8	27	20	10	50	20·0	109	27	20	10	51	20·2	108
	P—n	7	25	37	9	58	91·0	89	25	37	9	59	91·0	89
	P—t	7	30	12	9	38	230·5	63	30	12	9	39	229·9	64
8	P—q	7-8	27	17	10	52	19·9	105	27	17	10	52	20·0	104
	P—n	7	25	34	10	0	93·3	87	25	34	10	0	94·0	86
	P—t	7	30	9	9	41	229·2	66	30	9	9	41	228·7	67
9	P—q	7-8	27	14	10	53	19·7	102	27	13	10	54	19·6	101
	P—n	7	25	31	10	1	95·4	85	25	30	10	2	96·1	85
	P—t	7	30	6	9	42	228·1	69	30	5	9	43	227·8	70
10	P—q	7-8	27	9	10	55	18·8	98	27	7	10	55	18·7	96
	P—n	7	25	26	10	3	97·6	83	25	24	10	3	98·4	82
	P—t	7	30	1	9	44	227·8	73	29	59	9	44	227·7	74
11	P—q	7-8	27	2	10	57	17·8	93	27	0	10	57	17·2	92
	P—n	7	25	19	10	5	100·7	81	25	17	10	5	101·6	79
	P—t	7	29	54	9	46	227·2	78	29	52	9	46	227·3	80
12	P—q	7-8	26	54	10	58	16·1	88	26	51	10	59	15·3	87
	P—n	7	25	11	10	6	104·2	77	25	8	10	7	105·2	76
	P—t	7	29	46	9	47	227·1	84	29	43	9	48	227·3	86
13	P—q	7-8	26	44	11	0	13·6	83	26	40	11	1	12·5	82
	P—n	7	25	1	10	8	107·4	74	24	57	10	9	109·4	72
	P—t	7	29	35	9	49	227·3	90	29	31	9	50	227·6	92
14	P—q	7-8	26	33	11	2	10·3	78	26	29	11	3	9·1	76
	P—n	7	24	50	10	10	112·7	70	24	46	10	11	114·1	69
	P—t	7	29	24	9	51	227·8	97	29	20	9	52	228·2	99

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Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point.	Dec. of Middle Point.	Position Angle.	Distance.	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point.	Dec. of Middle Point.	Position Angle.	Distance.
			h m s	° ′	°	′	h m s	° ′	°	′
Aug. 15	P—*q*	7–8	23 26 21	−11 4	6·3	73	23 26 16	−11 5	4·8	72
	P—*n*	7	24 38	10 12	117·9	66	25 33	10 13	119·7	65
	P—*s*	7–8	28 9	9 57	216·5	76	28 40	9 58	217·5	78
16	P—*q*	7–8	26 5	11 7	0·0	69	26 2	11 7	358·9	67
	P—*n*	7	24 22	10 15	124·5	62	24 19	10 15	127·0	62
	P—*s*	7–8	27 53	10 0	219·0	84	27 50	10 0	219·1	86
17	P—*q*	7–8	25 50	11 9	353·6	64	25 46	11 10	351·7	64
	P—*n*	7	24 7	10 17	132·7	59	24 3	10 18	134·8	58
	P—*s*	7–8	27 38	10 2	220·8	92	27 34	10 3	221·3	94
18	P—*q*	7–8	25 33	11 11	345·3	60	25 27	11 12	342·7	61
	P—*n*	7	23 50	10 19	142·2	57	23 45	10 20	144·9	56
	P—*s*	7–8	27 21	10 4	222·5	102	27 16	10 5	223·2	104
19	P—*m*	7	23 2	11 27	26·4	90	22 55	11 27	24·9	87
	P—*n*	7	23 32	10 22	152·1	55	23 25	10 22	156·1	56
	P—*r*	8	26 45	11 0	292·0	75	26 38	11 0	289·7	77
20	P—*m*	7	22 42	11 29	22·0	82	22 36	11 30	20·3	79
	P—*n*	7	23 12	10 24	163·3	56	23 6	10 25	166·8	58
	P—*r*	8	26 26	11 3	286·3	82	26 20	11 3	284·4	85
21	P—*m*	7	22 21	11 32	16·0	74	22 14	11 32	13·9	71
	P—*n*	7	22 51	10 27	174·3	59	22 44	10 27	177·7	61
	P—*r*	8	26 5	11 5	281·4	91	25 58	11 5	279·8	94

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22	P—*m*	7	22	0	11	34	8·7	67	21	52	64
	P—*n*	7	22	30	10	29	183·9	64	22	22	67
	P—*q*	7–8	24	13	11	21	306·2	68	24	4	70
23	P—*m*	7	21	36	11	37	358·3	60	21	28	59
	P—*n*	7	22	6	10	32	193·2	71	21	58	74
	P—*q*	7–8	23	49	11	24	297·1	75	23	41	77
24	P—*n*	7	21	41	10	34	200·7	80	21	33	83
	P—*q*	7–8	23	24	11	26	291·9	84	23	16	87
	P—*l*	8	17	37	11	12	90·0	92	17	29	88
25	P—*n*	7	21	15	10	37	207·2	90	21	7	94
	P—*q*	7–8	22	58	11	29	284·8	94	22	50	98
	P—*l*	8	17	11	11	15	93·6	79	17	3	75
26	P—*n*	7	20	51	10	40	212·4	101	20	40	105
	P—*q*	7–8	22	34	11	32	280·4	106	22	23	110
	P—*l*	8	16	47	11	18	98·6	67	16	36	63
27	P—*n*	7	20	22	10	42	216·9	113	20	13	117
	P—*m*	7	19	52	11	47	307·1	66	19	43	69
	P—*l*	8	16	17	11	20	105·9	55	16	8	51
28	P—*i*	5–6	14	51	10	55	138·2	101	14	41	99
	P—*k*	7	14	11	11	58	59·9	100	14	1	95
	P—*m*	7	19	24	11	50	296·9	75	19	14	79
29	P—*i*	5–6	14	21	10	57	146·7	96	14	12	95
	P—*k*	7	13	40	12	0	57·9	85	13	31	80
	P—*m*	7	18	54	11	52	289·6	86	18	45	90

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Day. 1877.	Star Comparison	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point.			Dec. of Middle Point.		Position Angle.	Distance.	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point.			Dec. of Middle Point.		Position Angle.	Distance.
			h	m	s	°	′	°	′	h	m	s	°	′	°	′
Aug. 30	P—ι	5–6	23	13	52	−11	0	156·1	94	23	13	42	−11	1	159·0	93
	P—h	7		13	12	12	3	55·0	70		13	2	12	4	53·5	66
	P—m	7		18	25	11	55	284·1	99		18	15	11	56	282·9	103
31	P—λ	8		15	23	11	37	239·8	42		15	13	11	38	241·8	47
	P—f	6–7		11	13	11	34	107·3	91		11	3	11	35	108·9	86
	P—h	7		12	42	12	5	50·5	55		12	32		6	47·9	51
Sept. 1	P—λ	8		14	52	11	40	243·1	58		14	42	11	41	244·4	63
	P—f	6–7		10	42	11	37	114·2	78		10	32	11	38	116·5	74
	P—h	7		12	11	12	8	42·4	41		12	1	12	9	37·6	37
2	P—λ	8		14	19	11	42	245·2	74		14	9	11	43	246·1	79
	P—f	6–7		10	10	11	39	123·8	67		10	0	11	40	127·0	63
	P—g	7–8		10	29	12	6	70·7	48		10	19	12	7	69·8	43
3	P—h	6–7		11	8	12	13	278·0	21		10	58	11	9	294·9	21
	P—g	7–8		9	58	12	8	68·6	33		9	48	12	9	68·7	28
	P—λ	8		13	48	11	45	247·0	89		13	38	11	46	247·1	95
4	P—f	6–7		9	6	11	44	152·2	52		8	56	11	45	157·9	51
	P—h	6–7		10	35	12	15	309·4	25		10	25	12	16	301·3	29
	P—g	7–8		9	26	12	11	64·5	15		9	16	12	12	58·0	10
5	P—g	7–8		8	54	12	13	336·6	3		8	43	12	14	282·8	7
6	f—g	{6–7 / 7–8}		8	36	11	48	349·7	54		8	36	11	48	349·7	54

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	P—*g*	7-8		8	21	12	15	265·3	17		8	10	12	15	263·4	26
	P—*f*	6-7		8	1	11	48	188·0	55		7	50	11	49	193·1	57
7	P—*f*	6-7		7	29	11	50	202·1	63		7	18	11	51	206·1	66
	P—*h*	6-7		8	58	12	21	273·1	67		8	47	12	22	272·0	73
	P—*e*	8		3	49	12	24	84·1	84		3	38	12	24	84·5	79
8	P—*f*	6-7		6	56	11	52	212·5	74		6	45	11	53	215·4	77
	P—*h*	6-7		8	25	12	23	270·0	83		8	14	12	24	269·2	88
	P—*e*	8		3	16	12	26	88·7	68		3	5	12	27	88·7	62
9	P—*f*	6-7		6	23	11	54	220·0	86		6	12	11	54	222·1	90
	P—*g*	7-8		6	43	12	21	258·8	67		6	32	12	21	258·7	71
	P—*e*	8		2	43	12	28	88·6	52		2	32	12	28	88·8	47
10	P—*d*	8		1	27	11	48	145·2	102		1	16	11	48	148·0	100
	P—*g*	7-8		6	11	12	22	258·8	82		6	0	12	22	258·8	87
	P—*e*	8		2	12	12	29	93·2	36		2	1	12	29	95·5	31
11	P—*g*	7-8		5	39	12	24	258·8	97		5	28	12	24	258·8	106
	P—*e*	8		1	41	12	31	103·5	21		1	30	12	31	111·0	16
	P—*d*	7-8		0	56	11	50	153·8	97		0	45	11	50	156·8	96
12	P—*g*	7-8		5	8	12	25	258·8	113		4	57	12	25	258·8	118
	P—*e*	8		1	10	12	32	144·5	10		0	59	12	32	176·8	9
	P—*d*	7-8	23	0	25	11	51	162·9	94	23	0	14	11	51	166·1	94
13	P—μ	8	22	59	11	12	44	70·5	36	22	59	1	12	45	69·3	31
	P—*e*	8	23	0	39	12	33	222·9	13	23	0	29	12	34	232·2	18
	P—*d*	7-8	22	59	54	11	52	172·1	93	22	59	44	11	53	175·2	93

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Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations.) R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′
Sept. 14	P--μ	8	22 58 41	−12 45	63·8	21	22 58 31	−12 46	58·0	17
	P—e	8	23 0 9	12 34	242·4	27	59 59	12 35	245·7	31
	P—d	7–8	22 59 24	11 53	181·2	94	59 14	11 54	184·2	95
15	P—d	7–8	58 55	11 54	189·6	97	58 45	11 54	192·2	99
	P—c	6–7	55 45	13 13	51·1	99	55 35	13 13	49·7	94
	P—e	8	59 40	12 35	249·8	41	59 30	12 35	250·7	45
16	P—d	7–8	58 25	11 55	197·2	103	58 15	11 55	199·5	104
	P—c	6–7	55 16	13 14	46·2	87	55 6	13 14	44·1	84
	P—e	8	59 11	12 36	253·0	55	59 2	12 36	254·2	59
17	P—d	7–8	57 59	11 56	203·9	108	57 50	11 56	205·7	111
	P—c	6–7	54 49	13 15	39·8	77	54 40	13 15	37·2	74
	P—e	8	58 44	12 37	255·3	68	58 35	12 37	256·0	72
18	P—d	7–8	57 32	11 56	209·6	115	57 23	11 56	211·4	117
	P—c	6–7	54 22	13 15	32·2	68	54 13	13 15	28·8	66
	P—μ	8	56 49	12 48	276·1	36	56 40	12 48	275·2	40
19	P—c	6–7	53 57	13 15	23·0	62	53 49	13 16	19·5	60
	P—b	7–8	51 12	12 48	88·4	104	51 4	12 49	88·3	101
	P—e	8	57 52	12 37	258·2	93	57 44	12 38	258·7	97
20	P—c	6–7	53 32	13 16	11·9	58	53 25	13 16	8·3	58
	P—b	7–8	50 47	12 49	88·1	92	50 40	12 49	88·1	89
	P—e	8	57 27	12 38	259·5	105	57 20	12 38	259·9	108

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21	P—*c*	6–7	53	9	13	16	0·0	57	53	2	13	16	357·1	57
	P—*b*	7–8	50	24	12	49	87·9	81	50	17	12	49	87·8	77
	P—μ	8	55	36	12	49	272·3	71	55	29	12	49	272·2	75
22	P—*c*	6–7	52	47	13	15	350·1	58	52	39	13	15	346·6	59
	P—*b*	7–8	50	2	12	48	87·6	70	49	54	12	48	87·4	67
	P—μ	8	55	14	12	49	272·3	82	55	6	12	49	272·3	85
23	P—*c*	6–7	52	26	13	15	340·8	61	52	19	13	15	337·9	63
	P—*b*	7–8	49	41	12	48	86·2	60	49	34	12	48	86·0	57
	P—μ	8	54	55	12	49	272·4	92	54	46	12	49	272·5	96
24	P—*c*	6–7	52	6	13	15	332·9	66	52	0	13	14	330·9	68
	P—*b*	7–8	49	21	12	48	84·4	51	49	15	12	47	84·0	48
	P—μ	8	54	33	12	48	272·7	102	54	27	12	47	272·8	105
25	P—*c*	6–7	51	48	13	14	327·2	71	51	42	13	14	325·5	73
	P—*b*	7–8	49	3	12	47	81·6	42	48	57	12	47	80·4	39
	P—μ	8	54	15	12	47	273·2	111	54	9	12	47	273·3	114
26	P—*c*	6–7	51	30	13	13	322·6	78	51	25	13	13	321·3	79
	P—*b*	7–8	48	45	12	46	76·3	33	48	40	12	46	75·3	31
	P—*a*	6–7	48	26	12	29	121·8	49	48	21	12	29	123·2	48
27	P—*c*	6–7	51	14	13	12	319·3	84	51	10	13	12	318·2	86
	P—*b*	7–8	48	29	12	45	68·4	27	48	25	12	45	66·4	25
	P—*a*	6–7	48	11	12	28	124·9	42	48	7	12	28	126·7	40
28	P—*c*	6–7	51	0	13	11	316·7	91	50	56	13	11	316·3	92
	P—*b*	7–8	48	15	12	44	56·3	22	48	11	12	44	51·1	21
	P—*a*	6–7	47	56	12	27	128·9	35	47	52	12	27	130·9	34

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Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point.			Dec. of Middle Point.		Position Angle.	Distance.	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point.			Dec. of Middle Point.		Position Angle.	Distance.
			h	m	s	°	′	°	′	h	m	s	°	′	°	′
Sept. 29	*a*—*b*	7-7	22	47	19	−12	33	344·9	35	22	47	19	−12	33	344·9	35
	P—*b*	7-8		48	3	12	43	40·5	18		47	59	12	42	33·6	18
	P—*a*	6-7		47	44	12	26	132·6	29		47	40	12	25	134·3	27
30	*a*—*b*	7 & 7-8		47	19	12	33	344·9	35		47	19	12	33	344·9	35
	P—*b*	7-8		47	51	12	41	20·3	18		47	48	12	41	14·6	19
	P—*a*	6-7		47	32	12	24	137·5	23		47	29	12	24	138·8	21
Oct. 1	P—*a*	6-7		47	22	12	23	141·7	17		47	19	12	22	143·1	16
	P—*b*	7-8		47	41	12	40	3·6	21		47	38	12	39	0·0	22
2	P—*a*	6-7		47	13	12	21	147·4	12		47	11	12	20	149·0	10
	P—*b*	7-8		47	32	12	38	353·1	24		47	30	12	37	351·1	25
3	P—*a*	6-7		47	6	12	19	154·2	7		47	4	12	18	158·2	5
	P—*b*	7-8		47	25	12	36	347·3	29		47	23	12	35	345·9	30
4	P—*a*	6-7		47	2	12	17	166·6	3		47	0	12	16	180·0	1
	P—*b*	7-8	22	47	21	−12	34	345·0	33	22	47	19	−12	33	344·3	34

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On the Opposition of the Minor Planet Ariadne as a means of determining the Solar Parallax. By Mr. David Gill.

The minor planet *Ariadne* (43) is in opposition on July 24 of the present year, in circumstances very favourable for determining its diurnal parallax by the heliometric method. The distance of the planet from the Earth is 0·83, the Sun's mean distance from the Earth being 1.

Its declination (−15°) is not far from the most favourable position for observation at Ascension, and opposition occurs ten days before it is possible to begin to observe *Mars* satisfactorily. The observations can therefore be made without inconvenience or additional expense.

It is true the planet is somewhat faint (8·8 mag.), but experience at Mauritius has taught me that with such a heliometer as Lord Lindsay's, in a tropical sky, 8·5 mag. stars can be measured with more accuracy than any other, and that 9th mag. stars can be well measured in favourable atmospheric conditions.

The geometrical conditions are very much more favourable than in the case of *Juno* (the distance of *Juno* at opposition was 1·05); and, besides, it is possible to select more suitable stars of comparison. The opportunity therefore appears a very good one, and I have accordingly selected stars of comparison, of which the subjoined is a list.

In addition to this list, absolutely required for comparison with the planet, are a few stars required in the triangulation of the comparison stars, the latter are denoted by Greek letters.

The plan of observation is given in connection with the following tables, as also the plan of triangulation of the stars of comparison.

I shall be greatly indebted to any astronomer who will assist this determination in any of the following ways:—

1. By meridian observations of the stars of comparison.

2. By extra-meridian determinations of the difference of R.A. and declination of any of the stars of comparison, but especially by accurate measures of the difference of declination of the stars *f*, *c*. These stars will be used by me to determine the zero of the position-circle in the triangulation, and, as they do not differ 2′ in declination, the observation can be made by means of the wire micrometer with very great accuracy.

3. By heliometer measures, either of the star and planet, or of the distances and position-angles of the stars included in the plan of triangulation.

4. By a series either of meridian or extra-meridian observations of the planet, extending as far as possible on both sides of opposition.

The oppositions of *Iris* (7) and *Melpomene* (18) are also very favourable. I will notice them more at length at the next meeting of the Society.

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Stars to be observed with Ariadne at Opposition 1877.

Adopted Name of Star.	Approximate R.A. h m s	Dec. ° ′	No. in Oeltzen's Argelander.		No. in Lalande.		No. in Weisse's Bessel.		No. in Santini.		Remarks.
a	20 8 28	−15 8	20345	8–9							
b	20 12 9	−14 39	20392	7–8							
c	20 12 57	−15 23	20407	8							
d	20 16 34	−14 39	...	....	39140	7½	...		...		Also in Berlin Acad. Star Cat.
e	20 18 24	−15 13	20489	8–9	39210	8½					
f	20 19 10	−15 22	20496	7–8	39247	8					
a	20 19 27	−14 16	...	...	...	...	xx. 445	8	1850	7–8	
β	20 22 8	−15 27	20541	9							
γ	20 25 2	−14 11	...	...	39486	8	588	9	1859	9	
g	20 27 21	−14 9	...	...	39579	7	646	7	1865	7	
k	20 27 52	−14 52	...	...	...	...	664	9			
h	20 29 23	−15 44	20642	8	39671	9					

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Plan of Heliometric Triangulation of Stars to be compared with Ariadne.

Stars.	Mag.	R.A. h m s	Dec. ° ′	Position Angle. °	Dist. ′
a—b	8-9—7-8	20 10 19	−14 54	241·6	61
a—c	8-9—8	10 43	15 16	283·0	67
b—c	7-8—8	12 33	15 1	345·2	46
b—d	7-8—7-8	14 22	14 39	270	64
b—e	7-8—8-9	15 17	14 56	290·6	97
b—α	7-8—7-8	15 48	14 28	257·8	108
c—d	8—7-8	14 46	15 1	230·0	68
c—e	8—8-9	15 41	15 18	262·8	80
c—α	8—7-0	16 12	14 50	234·6	116
d—e	7-8—8-9	17 29	14 56	322·0	43
d—f	7-8—7-8	17 52	15 1	318·8	57
d—α	7-8—7-8	18 1	14 28	241·2	48
d—β	7-8—9	19 21	15 3	300·7	94
e—f	8-9—7-8	18 47	15 18	309·0	14
e—α	8-9—7-8	18 56	14 45	195·0	59
e—β	8-9—9	20 16	15 20	284·5	56
e—γ	8-9—8-9	21 43	14 42	237·2	114
f—α	7-8—7-8	19 19	14 49	183·7	66
f—β	7-8—9	20 39	15 25	276·6	43
f—γ	7-8—8-9	22 6	14 47	230·2	111
g—h	7—8-9	28 22	14 57	342·8	99
g—α	7—7-8	23 24	14 13	86·5	115
g—β	7—9	24 45	14 48	44·2	109
g—γ	7—8-9	26 12	14 10	86·6	34
h—β	8-9—9	25 46	15 36	99·2	106
h—γ	8-9—8-9	27 13	14 58	145·9	112
α—β	7-8—9	20 48	14 52	331·2	81
α—γ	7-8—8-9	22 15	14 14	226·5	81
β—γ	9—8-9	23 35	14 48	209·0	87
k—g	9—7	27 37	14 31	170·0	44
k—h	9—8-9	28 38	15 18	337·0	57
k—β	9—9	25 0	15 10	67·8	90
k—γ	9—8-9	20 26 27	−14 32	134·9	58

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Plan of Observations of Ariadne and Comparison Stars.

[P denotes the planet; other letters the stars in the preceding list.]

Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′
July 13	P—*f*	7–8	20 22 40	−15 10	76·7	104	20 22 31	−15 10	76·1	100
	P—*g*	7	26 46	14 34	199·3	52	26 37	14 34	203·8	54
	P—*h*	8–9	27 47	15 21	314·6	65	27 38	15 21	312·0	69
	P—*k*	9	27 1	14 55	255·5	26	26 52	14 55	257·7	30
14	P—*f*	7–8	22 13	15 10	74·8	92	22 4	15 10	74·1	87
	P—*g*	7	26 19	14 34	211·7	58	26 10	14 34	215·2	60
	P—*h*	8–9	27 20	15 21	307·6	75	27 11	15 21	305·7	79
	P—*k*	9	26 34	14 55	260·7	38	26 25	14 55	261·8	43
15	P—*f*	7–8	21 46	15 10	72·3	79	21 37	15 10	71·3	75
	P—*g*	7	25 52	14 34	221·5	65	25 43	14 34	224·2	68
	P—*h*	8–9	26 53	15 21	302·3	86	26 44	15 21	300·8	90
	P—*k*	9	26 7	14 55	263·3	51	25 58	14 55	263·8	55
16	P—*e*	8–9	20 56	15 6	78·6	75	20 47	15 6	78·0	70
	P—*g*	7	25 24	14 34	229·0	75	25 15	14 34	231·3	78
	P—*h*	8–9	26 25	15 21	298·2	97	26 15	15 21	297·0	101
	P—*k*	9	25 40	14 55	264·7	64	25 30	14 55	265·0	69
17	P—*d*	7–8	19 33	14 49	102·4	88	19 23	14 49	103·1	84
	P—*f*	7–8	20 51	15 10	63·8	54	20 41	15 10	61·4	50

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	P—g	7	24	56	14	34	235·1	86	24	47	14	34	236·7	89
	P—k	9	25	12	14	55	265·5	78	25	2	14	55	265·8	82
18	P—d	7–8	19	4	14	49	104·7	75	18	55	14	49	105·6	71
	P—f	7–8	20	22	15	10	55·4	42	20	13	15	10	51·8	39
	P—g	7	24	28	14	34	239·7	97	24	19	14	34	241·0	101
	P—k	9	24	43	14	55	266·1	92	24	34	14	55	266·2	96
19	P—d	7–8	18	36	14	49	108·4	62	18	27	14	49	109·8	58
	P—e	8–9	19	31	15	6	65·8	35	19	22	15	6	62·6	31
	P—k	9	24	15	14	55	266·5	105	24	6	14	55	266·6	110
	P—c	8	16	47	15	11	77·6	114	16	38	15	11	77·1	110
	P—β	9	21	23	15	13	322·2	36	21	14	15	13	317·1	39
20	P—c	8	16	18	15	11	76·0	100	16	9	15	11	75·5	96
	P—d	7–8	18	7	14	49	113·9	49	17	58	14	49	116·3	45
	P—e	8–9	19	2	15	6	52·0	23	18	53	15	6	44·6	20
	P—a	7–8	19	33	14	37	176·1	43	19	24	14	37	178·1	43
	P—β	9	20	54	15	13	308·1	46	20	45	15	13	304·7	49
21	P—b	7–8	15	25	14	49	102·0	97	15	16	14	49	102·7	93
	P—e	8	15	49	15	11	74·0	86	15	40	15	11	73·3	82
	P—d	7–8	17	38	14	49	123·3	37	17	29	14	49	127·7	33
	P—e	8–9	18	33	15	6	16·6	14	18	24	15	6	359·0	14
	P—a	7–8	19	4	14	38	194·4	45	18	55	14	38	199·7	46
	P—β	9	20	25	15	13	299·0	57	20	16	15	13	296·9	61
22	P—b	7–8	14	56	14	49	104·4	83	14	47	14	49	105·3	79
	P—c	8	15	20	15	11	71·6	73	15	10	15	11	70·4	69

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Day. 1877.	Stars of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′
July 22	P—*e*	8–9	20 18 4	−15 6	323·1	17	20 17 54	−15 6	312·1	20
	P—*a*	7–8	18 35	14 38	210·0	50	18 26	14 38	214·2	53
	P—*β*	9	19 56	15 13	293·1	70	19 46	15 13	291·6	74
23	P—*e*	8	14 51	15 12	67·4	60	14 41	15 12	66·0	55
	P—*d*	7–8	16 40	14 50	172·9	21	16 30	14 50	185·1	22
	P—*e*	8–9	17 35	15 7	297·9	27	17 25	15 7	293·0	31
	P—*a*	7–8	14 27	14 50	221·4	59	14 18	14 50	224·6	62
24	P—*e*	8	14 22	15 12	61·7	47	14 12	15 12	59·1	43
	P—*b*	7–8	13 58	14 50	112·7	57	13 48	14 50	114·5	53
	P—*e*	8–9	17 6	15 7	287·7	40	16 56	15 7	285·7	44
	P—*d*	7–8	16 11	14 50	207·7	25	16 1	14 50	214·4	27
25	P—*a*	8–9	11 39	15 4	86·0	93	11 30	15 4	86 0	88
	P—*b*	7–8	13 30	14 50	120·5	45	13 21	14 50	123·8	41
	P—*e*	8–9	16 37	15 7	282·4	53	16 28	15 7	281·3	57
	P—*d*	7–8	15 42	14 50	228·0	34	15 33	14 50	232·6	38
26	P—*a*	8–9	11 10	15 5	85·8	79	11 1	15 5	85·8	74
	P—*b*	7–8	13 1	14 51	132·6	34	12 52	14 51	139·8	31
	P—*e*	8–9	16 8	15 8	279·3	67	15 59	15 8	278·4	71
27	P—*a*	8–9	10 41	15 6	85·7	64	10 32	15 6	85·6	60
	P—*b*	7–8	12 32	14 51	155·6	26	12 23	14 51	165·3	25
	P—*e*	8–9	15 39	15 8	277·1	80	15 30	15 8	276·5	85

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28	P—*a*	8–9		10	13	15	6	85·4	51		10	4	15	7	85·3	46
	P—*b*	7–8		12	3	14	51	186·6	25		11	54	14	52	196·1	26
	P—*d*	7–8		14	16	14	51	249 6	71		14	7	14	52	250·6	76
	P—*e*	8–9		15	11	15	8	275·6	94		15	2	15	9	275·2	98
29	P—*a*	8–9		9	45	15	6	85·1			9	36	15	7	84·9	33
	P—*b*	7–8		11	35	14	52	212·6	31		11	26	14	53	218·7	33
	P—*e*	8		11	59	15	14	302·7	34		11	50	15	15	299·1	37
30	P—*a*	8–9		9	17	15	7	84·7	24		9	8	15	7	84·3	19
	P—*b*	7–8		11	8	14	52	227·8	40		10	59	14	52	231·8	44
	P—*e*	8		11	31	15	14	292·3	45		11	22	15	14	290·3	49
31	P—*a*	8–9		8	50	15	7	83·4	10		8	40	15	7	81·2	7
Aug. 1	P—*a*	8–9	20	8	22	−15	8	270·0	3	20	8	13	−15	8	270·0	7

Notes.

July 13. If *k* is bright enough it will be best to use the stars *f* and *k* to determine the parallax, measuring to *g* and *h* only once. If *k* be too faint then *g* and *h* must be symmetrically measured.

14. Same remarks apply as to July 13.

15. Do. do.

16. Parallax to depend on *k* and *e*, if *k* bright enough; if not, use *g* and *h*, as on July 13.

17. Endeavour to measure all stars; if only time for once, then in following order—*k*, *d*, *f*, *g*; if *k* too faint, measure *g* twice, thus—*d*, *g*, *g*, *f*.

18. Same as on 17th.

19. If *k* bright enough, use *k*, *c*, and *β*; if not, measure *f*—*d*, P—*d*, P—*f*.

July 20. Endeavour to measure all these in the following order:

21. Measure *a*, *b*, *c*, *β*.

22. Same as 21st.

23. Measure *c*, *e*, *a*, and *d*.

24. Measure *c*, *e*, *d*, and *b*.

25. Measure *a*, *e*, *d*, and *b*.

26. Parallax depends on *a* and *e*; measure *b* once only.

27. Same as 26th.

28. Same as 26th.

29. Measure *a* twice; *b* and *c* once each.

30. Same as 29th.

31. Measure position-angles also.

Aug. 1. Same as 31st.

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Nébuleuses nouvelles découvertes et observées à l'Observatoire de Marseille. Par M. E. Stephan.

Positions moyennes pour 1876·0.

N° d'ordre.	* de comp.	Ascensions droites. h	m	s	Distances polaires. °	′	″	Description sommaire.
1	*a*	0	33	17·56	87	8	41·6	Excessivement excessivement faible; excessivement petite; quelques petits points brillants visibles par intermittences.
2	*b*	0	34	36·47	87	14	27·1	Noyau nébuleux excessivement excessivement faible et petit.
3	*c*	0	35	48·42	54	21	6·9	Excessivement excessivement faible; excessivement petite; ronde; graduellement condensée au centre; un très-petit point brillant à peu près central.
4	*d*	1	16	58·47	79	21	25·3	Excessivement excessivement faible; aspect vaporeux; très-petite; enveloppe une très-petite *; en touche une autre 14–15^{me}.
5	*e*	1	24	1·87	69	12	2·1	Excessivement excessivement faible; presque inobservable; irrégulièrement arrondie; diamètre = $\frac{1}{2}$ de 1′ environ.
6	*f*	1	31	10·20	55	15	56·8	Excessivement excess. faible et petite; enveloppe plusieurs très-petites *.
7	*g*	1	53	9·86	59	17	25·5	Excessivement excessivement faible; très-petite; ronde; un peu de condensation centrale.
8	*h*	1	53	55·49	58	43	4·2	Excessivement excessivement faible; petite; aspect vaporeux; irregulièrement arrondie; très-petit point brillant; touche très-petite *.
9	*h*	1	54	28·84	58	46	26·7	Excessivement excessivement faible et petite; enveloppe une très-petite *.
10	*i*	2	48	52·52	90	41	17·4	10 et 11 sont accolées et forment une sorte de nébuleuse à 2 noyaux; elles sont à peu près identiques; toutefois 10 est un peu plus faible que 11. Toutes deux excessivement excessivement faibles et petites; rondes avec condensation centrale.
11	*i*	2	48	49·77	90	41	1·0	
12	*j*	21	20	8·87	97	31	53·1	Excessivement excess. faible et petite; ronde; très-petit point brillant central.
13	*k*	22	16	10·81	94	44	41·4	Excessivement excessivement faible; irrégulièrement arrondie; diamètre = $\frac{1}{2}$ 1′ environ; trace de condensation centrale.

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14	*l*		22	16	57·19	54	24	39·3	Faible; très-petite; ronde; forte condensation centrale.
15	*l*		22	18	38·39	54	25	34·2	15, 16 et 17 ont à peu près le même aspect que 14; 15 est un peu plus faible et plus petite; 16 est un peu plus brillante et moins petite; 17 est notablement plus faible et plus petite.
16	*l*		22	18	40·04	54	30	4·0	
17	*l*		22	18	43·19	54	32	21·8	
18	*m*		22	22	28·50	73	51	1·6	Excessivement excessivement faible et petite; ronde; légère condensation centrale, avec un très-petit point brillant à peu près central.
19	*n*	•	22	30	13·70	56	41	46·8	Les quatre nébuleuses 19, 20, 21 et 22 sont excessivement excessivement faibles; excessivement petites; très-difficilement observables. La plus belle est 19; puis viennent 20, 21, 22. Cependant 22, quoique la plus petite des quatre, est plus brillante.
20	*n*		22	30	19·22	56	40	30·7	
21	*n*		22	30	24·27	56	39	52·4	
22	*n*		22	30	24·92	56	41	35·2	
23	*o*		22	32	56·70	56	34	23·6	Excessivement excessivement faible; excessivement petite; ronde; un peu de condensation centrale enveloppe quelques très-petites étoiles.
24	*p*		22	41	56·69	50	24	56·1	Excessivement excess. faible; très-petite; ronde; légère condensation centrale.
25	*q*		22	52	44·36	54	51	38·6	Excessivement excess. faible; très-petite; irrégulièrement arrondie; condensation centrale mal définie; plusieurs très-petits points brillants.
26	*r*		22	55	23·47	88	24	12·3	Excessivement excessivement faible, à peine observable; ronde D = 1″·5; condensation centrale à peine sensible.
27	*s*		23	6	32·63	55	47	6·2	Excessivement excess. faible, à peine observable; irrégulièrement arrondie D = 45″; condensation à peine sensible; quelques points br. soupçonnés.
28	*t*		23	10	18·64	66	10	44·5	Excessivement excessivement faible; modérément étendue; irrégulièrement arrondie; enveloppe plusieurs très-petites étoiles.
29	*u*		23	20	30·76	65	36	4·9	Excessivement excessivement faible et petite; irrégulièrement arrondie; une peu de condensation centrale; enveloppe un très-petite *.
30	*v*		23	46	55·11	62	24	19·5	Excessivement faible et petite; ronde; condensation centrale.

Le No. 12 est peut-être identique avec 440 Lassell.
14, 15, 16, 17 sont voisines de 474 et 475 Lassell, mais distinctes de celles-ci.

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Positions Moyennes des Étoiles de Comparaison pour 1876·0.

*	Noms des étoiles.	Ascensions droites. h m s	Distances polaires. ° ′ ″	Autorité.
a	88 Arg. Z+ 2	0 34 58·59	87 4 54·1	A. Cat. de Weisse, N° 583 H. 0.
b	92 Arg. Z+ 2	0 35 40·27	87 12 57·8	1 obs. méridienne.
c	129 Arg. Z+35	0 35 47·97	54 20 24·6	1 obs. mérid.
d	169 Arg. Z+10	1 15 9·61	79 22 41·1	A. Cat. de Weisse, N° 215 H. 1.
e	236 Arg. Z+20	1 26 2·34	69 15 16·8	1 obs. mérid.
f	290 Arg. Z+34	1 32 34·98	55 18 56·5	1 obs. mérid.
g	311 Arg. Z+30	1 50 58·19	59 18 54·1	1 obs. mérid.
h	359 Arg. Z+31	1 56 24·64	58 42 32·1	1 obs. mérid.
i	456 Arg. Z 0	2 49 49·87	90 42 8·0	1 obs. mérid.
j	451 W. (*a.c.*); H. xxi.	21 20 49·09	97 32 58·0	A. Cat. de Weisse, N° 451 H. xxi.
k	238 W. (*a.c.*); H. xxii.	22 13 23·06	94 41 11·3	A. Cat. de Weisse.
l	4794 Arg. Z+35	22 19 50·96	54 27 3·0	1 obs. mérid.
m	4744 Arg. Z+16	22 21 37·95	73 51 21·7	1 obs. mérid.
n	4531 Arg. Z+33	22 27 36·57	56 41 38·3	A. Cat. de Weisse, N° 584 H. xxii.
o	4561 Arg. Z+33	22 34 26·29	56 32 14·0	1 obs. mérid.
p	4953 Arg. Z+39	22 46 41·51	50 23 35·0	Cat. de Groombr., N° 3908.
q	4942 Arg. Z+35	22 55 3·89	54 49 35·5	1 obs. mérid.
r	4674 Arg. Z+ 1	22 56 35·72	88 26 31·3	1 obs. mérid.
s	4858 Arg. Z+34	23 4 55·10	55 50 14·5	1 obs. mérid.
t	4711 Arg. Z+23	23 9 35·13	66 15 6·5	2 obs. mérid.
u	4766 Arg. Z+24	23 18 5·34	65 40 7·4	1 obs. mérid.
v	4641 Arg. Z+27	23 48 38·58	62 27 36·3	1 obs. mérid.

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Nébuleuses nouvelles découvertes et observées à l'Observatoire de Marseille. Par M. E. Stephan.

Positions moyennes pour 1877·0.

N° d'ordre.	* de comp.	Ascensions droites. h	m	s	Distances polaires. °	′	″	Description sommaire.
1	*a*	1	21	10·60	92	32	57·4	1 et 2 ont à peu près le même aspect; toutes deux sont excessivement excessivement faibles et petites; rondes; condensation centrale; 2 un peu moins faible que 1.
2	*a*	1	21	32·62	92	30	55·8	
3	*b*	1	59	11·68	46	0	51·8	Excessivement excess. faible; forme d'un mince fuseau à 45° avec le méridien longueur 1′·5 environ; léger noyau de condensation; observation difficile.
4	*c*	2	4	29·53	46	0	42·0	Excessivement excess. faible et petite; ronde; condensation centrale graduelle.
5	*d*	2	24	56·09	55	3	3·8	Excessivement excessivement faible; un peu ovoïde; grand diamètre = 1′·25 environ; faible condensation à peu près centrale.
6	*e*	2	31	37·87	101	33	35·1	Excessivement excessivement faible; très-petite; ronde; pas de condensation (à peine observable).
7	*e*	2	31	41·11	101	32	24·6	Plus faible que 6; très-petite; ronde; un petit point de condensation centrale.
8	*f*	2	41	11·89	85	52	34·6	Excessivement excessivement faible; très difficile à observer; petite; ronde; D = 0′·7; traces de condensation.
9	*f* et *g*	2	41	48·66	85	56	10·2	Excessivement faible; excessivement excessivement petite; ronde; belle condensation centrale; précédée de 2′ par une * 13ème sur même parallèle.
10	*h*	2	52	16·74	100	50	3·93	10 et 11 sont excessivement excessivement faibles; très-petites; rondes avec un peu de condensation centrale; 10 un peu moins faible que 11.
11	*h*	2	52	11·26	100	51	26·5	
12	*i*	3	24	8·69	95	57	50·1	Excessivement excessivement faible et petite; ronde; condensation centrale; suit de 2ᵐ·2 une * 13ème.
13	*j*	3	54	49·09	67	12	48.5	Excessivement excess. faible; excessivement petite; irrégulièrement arrondie; légère condensation; une très-petite * se projette sur la nébuleuse.

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N° d'ordre.	* de comp.	Ascensions droites. h	m	s	Distances polaires. °	′	″	Description sommaire.
14	*k*	3	58	22·39	64	55	45·0	Excessivement faible et petite ; ronde ; condensation centrale ; assez marquée ; paraît résoluble.
15	*l*	4	22	14·81	95	27	13·8	Excessivement faible et petite ; ronde ; paraît résoluble.
16	*m*	4	48	12·07	86	55	59·9	Très-faible et très-petite ; nébulosité enveloppant une * 11ème.
17	*n*	5	8	18·65	100	46	12·1	Très-faible ; et très-petite ; ronde ; légère condensation centrale.
18	*o*	5	57	41·25	99	43	46·8	Très-légère nébulosité enveloppant une * 12ème.
19	*p*	7	1	20·16	45	20	52·6	Excessivement excessivement faible ; très-petite ; irrégulière ; allongée.
20	*q*	7	27	6·24	56	54	43·0	Excessivement excessivement faible ; excessivement petite ; enveloppe plusieurs très-petites *.
21	*r*	7	29	30·56	71	50	46·0	Excessivement faible ; excessivement excess. petite ; condensation centrale.
22	*s*	7	38	34·65	50	40	17·8	22 et 23 sont deux petits noyaux nébuleux excessivement excess. faibles ; 23 est beaucoup plus faible que 22, et touche au S. une très-petite *.
23	*s*	7	38	37·07	50	41	17·3	
24	*t*	7	59	56·34	50	29	19·2	Excessivement faible ; très-petite ; trace de condensation.
25	*t*	8	0	52·61	50	31	16·4	Faible ; petite ; ronde ; condensation centrale.
26	*u*	8	3	49·90	64	25	54·8	26 et 27 sont excessivement excess. faibles ; à peine observables ; excess. petites ; rondes ; 26 est la plus faible des deux.
27	*u*	8	3	52·10	64	27	30·6	
28.	*v*	8	4	56·13	86	0	8·7	Excessivement faible et petite ; ronde ; condensation centrale ; bien marquée.
29	*w*	8	11	58·72	68	9	58·6	Excessivement excess. faible et petite ; ronde ; faible condensation centrale.
30	*x*	8	14	19·27	70	27	51·1	Excessivement excess. faible ; très-petite ; irrégulière ; aspect vaporeux ; touche une * 13ème.

Nota.—L'une de nébuleuses 1 ou 2 est peut-être identique avec l'une des deux 332, 333, J. F. W. Herschel.

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Positions Moyennes des Étoiles de Comparaison pour 1877·0.

*	Noms des étoiles.	Ascensions droites. h m s	Distances polaires. ° ′ ″	Autorité.
a	343 W. (*a.c.*); H. I.	1 21 42·13	92 37 22·9	Cat. Weisse.
b	425 Arg. Z+43°	1 58 16·16	46 1 1·5	1 observation méridienne.
c	451 Arg. Z+43	2 6 34·78	45 59 39·5	1 obs. mérid.
d	473 Arg. Z+34	2 28 50·69	55 3 15·7	1 obs. mérid.
e	Anonyme	2 30 8·04	101 30 7·3	1 obs. mérid.
f	449 Arg. Z+ 4	2 43 35·74	85 53 15·4	1 obs. mérid.
g	388 Arg. Z+ 3	2 42 47·16	85 57 16·3	1 obs. mérid.
h	875 W. (*a.c.*); H. ii.	2 50 58·21	100 52 14·4	1 obs. mérid.
i	391 W. (*a.c.*); H. iii.	3 23 20·31	95 58 38·9	Cat. Weisse.
j	610 Arg. Z+22	3 51 3·56	67 14 55·5	1 obs. mérid.
k	671 Arg. Z+25	3 57 29·79	64 53 59·4	1 obs. mérid.
l	386 W. (*a.c.*); H. iv.	4 19 39·54	95 26 4·1	Cat. W.
m	716 Arg. Z+ 3	4 50 32·72	86 54 33·8	Cat. W. (*a.c.*), N° 1080 H. iv.
n	135 W. (*a.c.*); H. v.	5 7 33·53	100 46 52·9	Cat. W.
o	1556 W. (*a.c.*); H. v.	6 1 8·77	99 43 33·3	Cat. W.
p	1596 Arg. Z+44	7 2 21·66	45 19 28·3	1 obs. mérid.
q	1554 Arg. Z+33	7 28 18·24	56 53 32·0	1 obs. mérid.
r	1670 Arg. Z+18	7 28 8·39	71 52 38·6	1 obs. mérid.
s	2012 Arg. Z+39	7 41 9·50	50 41 34·8	1 obs. mérid.
t	2062 Arg. Z+39	8 1 37·61	50 33 24·4	1 obs. mérid.
u	1872 Arg. Z+25	8 4 40·40	64 27 18·6	1 obs. mérid.
v	1920 Arg. Z+ 4	8 3 14·06	86 1 51·1	1 obs. mérid.
w	1798 Arg. Z+21	8 8 18·87	68 12 48·5	1 obs. mérid.
x	2004 Arg. Z+19	8 17 44·49	70 26 1·4	2 obs. mérid.

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Observations of Occultations of Stars by the Moon, 1875, 6, 7 (with the deduced Equations between the Errors of the Lunar Elements); and of the Phenomena of Jupiter's Satellites, made at the Radcliffe Observatory, Oxford; continued from Vol. XXXV. No. 8, of the "Monthly Notices."

(*Communicated by the Radcliffe Observer.*)

No.	Day and Year of Observation.	Name of Object.	Phenomenon.	☽'s Limb.	Oxford Mean Solar Time. h m s	Observer.
1	1875. Oct. 24	σ Leonis	Disapp.	Bright	17 31 54·4	F. B.
2	"	"	Reapp.	Dark	18 20 32·3	"
3	Nov. 8	χ Aquarii	Disapp.	Dark	9 20 45·4	K.
4	Dec. 9	19 Arietis	Disapp.	Dark	5 59 46·5	K. & F. B.
5	1876. Jan. 3	Lamont 23	Disapp.	Bright	7 38 32·7	L.
6	"	"	Reapp.	Bright	7 40 33·4	"
7	Feb. 2	27 Arietis	Disapp.	Dark	6 22 59·4	K. & F. B.
8	"	"	Reapp.	Bright	7 27 32·3	F. B.
9	March 4	B.A.C. 2097	Disapp.	Dark	10 54 58·4	K.
10	April 1	47 Geminorum	Disapp.	Dark	7 27 7·1	L. & F. B.
11	"	W.B. (2) VII. 81, 2	Disapp.	Dark	7 41 37·7	L. & F. B.
12	" 7	B.A.C. 4225	Disapp.	Dark	8 22 52·9	L.
13	"	f Virginis	Disapp.	Dark	11 31 47·7	L. & F. B.
14	July 13	ϵ Piscium	Disapp.	Bright	13 0 46·6	F. B.
15	"	"	Reapp.	Dark	13 54 28·9	"
16	" 16	23 Tauri	Disapp.	Bright	14 26 51·1	"
17	"	24 Tauri	"	"	14 57 45·4	"
18	"	η Tauri	"	"	14 59 17·3	"
19	"	23 Tauri	Reapp.	Dark	15 21 17·1	"
20	"	27 Tauri	Disapp.	Bright	15 33 14·9	"
21	"	26 Tauri	"	"	15 35 1·8	"
22	"	28 Tauri	"	"	15 35 44·7	"
23	"	η Tauri	Reapp.	Dark	15 52 12·1	"
24	Nov. 29	47 Arietis	Disapp.	Dark	7 51 .1·9	L. & H. B.
25	1877. Jan. 30	ρ Leonis	Disapp.	Bright	10 45 15·1	L.
"	"	"	"	"	10 45 15·8	H. B.
26	"	"	Reapp.	Dark	11 50 38·0	L.
27	Feb. 26	Regulus	Disapp.	Dark	12 39 1·8	L.
"	"	"	"	"	12 39 0·4	F. B.
28	"	"	Reapp.	Bright	13 44 41·0	L.
"	"	"	"	"	13 44 40·9	F. B.

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Notes.

No. 1. *σ Leonis*, disapp. The star seemed to hang on the Moon's limb for 3 or 4 seconds, but ultimately disappeared instantaneously.

„ 2. „ reapp. The observation doubtful; I turned round to verify my counting, and, on again looking in the telescope, the star seemed to reappear at that moment.

„ 4. 19 *Arietis*, disapp. The time noted is that at which I last saw the star, which seemed to disappear behind a dense cloud. (K.)

„ 7. 27 *Arietis*, disapp. The disappearance was instantaneous and the observation good; the unilluminated disk of the Moon was distinctly visible. (K.)

„ 8. „ reapp. At the reappearance the star was faint; the time noted is thought to be certainly within $0^s.5$; the Moon's motion in N.P.D. was very rapid. (F.B.)

„ 10, 11. 47 *Geminorum*, disapp., and W.B. (2) VII. 81, 2, disapp. Instantaneous; the unilluminated disk of the Moon distinctly visible. (F.B.) The R.A. and N.P.D. of W.B. (2) VII. 81, 2 are obtained from three observations made in 1877.

„ 12. B.A.C. 4225, disapp. Doubtful to a second.

„ 13. *f Virginis*, disapp. The star very faint just previous to disappearance. (Both observers.)

„ 14. *e Piscium*, disapp. The star appeared to hang for a few seconds on the Moon's limb, and then disappeared behind a projection.

„ 15. „ reapp. I am very doubtful about this time; probably too late.

„ 17. 24 *Tauri*, disapp. Faint at disappearance.

„ 18, 20. *η Tauri*, disapp, and 27 *Tauri*, disapp. At both these phenomena the star hung on the Moon's limb for 2^s, and overlapped it (the colour of the star being plainly distinguished from that of the Moon), and then disappeared instantaneously.

„ 21. 26 *Tauri*, disapp. Star very faint; observation doubtful.

„ 22. 28 *Tauri*, disapp. Disappearance instantaneous.

„ 23. *η Tauri*, reapp. The reappearance had taken place at the time noted, when I just saw it at the edge of the field of the telescope.

„ 25. *ρ Leonis*, disapp. and reapp. Unsteady; windy. (L.)

„ 27. *Regulus*, disapp. Disappearance instantaneous. (Both observers.)

In the following table of the errors of lunar elements resulting from the occultations, the Greenwich notation is used, and the elements of the *Nautical Almanac* are used uncorrected. All the computations have been made by Mr. Main by the method given in his treatise on *Spherical and Practical Astronomy*.

The observations are referred to by the Nos. of reference given above.

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No.								
1	+11·30 =	+0·6802 × e	−0·2425 × f	−0·6802 × x	+0·2427 × y	−0·2026 × t	−0·5396 × m	−0·9210 × n
2	−11·32 =	−0·2003 × e	−0·9794 × f	+0·2003 × x	+0·9794 × y	+0·3038 × t	+2·6554 × m	−0·9207 × n
3	+ 3·15 =	+0·8910 × e	+0·4384 × f	−0·8910 × x	−0·4388 × y	−0·1956 × t	−0·6335 × m	−0·9462 × n
4	+ 9·65 =	+0·6204 × e	−0·7656 × f	−0·6204 × x	+0·7662 × y	−0·4953 × t	+0·7812 × m	−0·9885 × n
5	− 5·95 =	−0·5388 × e	−0·8423 × f	+0·5388 × x	+0·8423 × y	−0·0272 × t	+1·5823 × m	−0·9379 × n
6	− 4·22 =	−0·5856 × e	−0·8105 × f	+0·5856 × x	+0·8105 × y	−0·0026 × t	+1·4311 × m	−0·9379 × n
7	+ 3·20 =	+0·9480 × e	+0·0988 × f	−0·9480 × x	−0·0974 × y	−0·3509 × t	+0·2551 × m	−0·9593 × n
8	− 8·36 =	−0·5222 × e	+0·8363 × f	+0·5222 × x	−0·8359 × y	+0·3814 × t	−2·2871 × m	−0·9597 × n
9	+ 7·72 =	+0·5331 × e	−0·7937 × f	−0·5331 × x	+0·7945 × y	−0·2254 × t	+2·4694 × m	−0·9728 × n
10	+ 1·82 =	+0·0979 × e	+0·9938 × f	−0·0979 × x	−0·9938 × y	−0·1504 × t	−1·4320 × m	−0·9689 × n
11	+10·64 =	+0·7904 × e	−0·4482 × f	−0·7904 × x	+0·4502 × y	−0·3753 × t	+1·3358 × m	−0·9689 × n
12	+ 5·93 =	−0·1375 × e	+0·9905 × f	+0·1375 × x	−0·9905 × y	−0·2164 × t	−2·5444 × m	−0·9305 × n
13	+ 9·02 =	+0·6400 × e	+0·7668 × f	−0·6400 × x	−0·7670 × y	−0·4068 × t	−2·1331 × m	−0·9293 × n
14	+ 7·23 =	+0·9904 × e	+0·0066 × f	−0·9904 × x	−0·0060 × y	−0·4202 × t	−1·9663 × m	−0·9342 × n
15	(−16·44) =	−0·4036 × e	+0·9132 × f	+0·4036 × x	−0·9131 × y	+0·4040 × t	−1·5849 × m	−0·9347 × n
16	(+28·23) =	+0·7560 × e	−0·5592 × f	−0·7560 × x	+0·5606 × y	−0·5870 × t	−3·1938 × m	−0·9765 × n
19	− 2·86 =	−0·9002 × e	+0·1621 × f	+0·9002 × x	−0·1601 × y	+0·5468 × t	+1·6832 × m	−0·9770 × n

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17	+ 0·83 =	+0·5623 × e	−0·7866 × f	−0·5623 × x	+0·7874 × y	−0·5064 × t	+0·5069 × m	−0·9768 × n
18	+ 7·24 =	+0·6224 × e	−0·7301 × f	−0·6224 × x	+0·7311 × y	−0·5282 × t	+0·2325 × m	−0·9768 × n
23	− 0·49 =	−0·9113 × e	−0·0108 × f	+0·9113 × x	+0·0130 × y	+0·4977 × t	+1·9306 × m	−0·9773 × n
20	− 2·72 =	+0·8974 × e	−0·1743 × f	−0·8974 × x	+0·1763 × y	−0·5425 × t	−1·6254 × m	−0·9771 × n
21	− 2·35 =	+0·6934 × e	+0·6430 × f	−0·6934 × x	−0·6418 × y	−0·2498 × t	−2·9640 × m	−0·9771 × n
22	+ 3·96 =	+0·8468 × e	−0·3687 × f	−0·8468 × x	+0·3705 × y	−0·5563 × t	−1·0790 × m	−0·9771 × n
24	+ 9·40 =	+0·9332 × e	+0·0671 × f	−0·9332 × x	−0·0653 × y	−0·4115 × t	−1·4271 × m	−0·9709 × n
25	+10·04 =	+0·9085 × e	+0·3815 × f	−0·9085 × x	−0·3807 × y	−0·5078 × t	−2·4465 × m	−0·9872 × n
26	− 9·99 =	−0·7485 × e	−0·6480 × f	+0·7485 × x	+0·6486 × y	+0·4860 × t	+2·4259 × m	−0·9868 × n
27	+12·98 =	+0·8393 × e	+0·5066 × f	−0·8393 × x	−0·5058 × y	−0·4928 × t	−0·6266 × m	−0·9988 × n
28	−10·29 =	−0·7653 × e	−0·6180 × f	+0·7653 × x	+0·6188 × y	+0·5145 × t	+0·5042 × m	−0·9987 × n

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Phenomena of Jupiter's Satellites.

No.	Day and Year of Obs.	Satellite.	Phenomenon.	Phase of Phenomenon.	Instrument.	Oxford Mean Solar Time of Observation. h m s	Greenwich Mean Solar Time from *N.A.* h m s	Observer
	1875.							
1	June 28	I	Occ. disapp.	First contact	10-foot	10 21 36·3		K.
	,,	,,	,,	Bisection	,,	10 23 6·1	10 31	,,
	,,	,,	,,	Last cont.	,,	10 27 5·4		,,
2	,,	II	Occ. disapp.	Bisection	,,	11 0 0·1		,,
	,,	,,	,,	Last cont.	,,	11 2 29·7	11 7	,,
	1876.							
3	May 8	I	Ecl. disapp.	Last seen	,,	12 17 8·1	12 21 55·9	L.
4	,, 9	I	Shad. egr.	Last seen	,,	11 32 21·7	11 40	,,
5	,,	I	Tr. egr.	First cont.	,,	11 41 20·2		,,
	,,	,,	,,	Last cont.	,,	11 46 59·4	11 51	,,
6	,, 13	II	Ecl. disapp.	Last seen	Heliom.	9 30 33·8	9 35 36·2	F. B.
7	,,	II	Occ. reapp.	First seen	10-foot	12 9 23·9		L.
	,,	,,	,,	Last cont.	,,	12 14 23·1		,,
	,,	,,	,,	First seen	Heliom.	12 8 48·0	12 17	F. B.
	,,	,,	,,	Last cont.	,,	12 13 27·2		,,
8	,, 16	I	Trs. ingr.	First cont.	10-foot	11 12 39·5		L.
	,,	,,	,,	Last cont.	,,	11 17 8·7	11 23	,,
9	,, 20	II	Occ. disapp.	First cont.	,,	11 53 29·3		,,
	,,	,,	,,	Last cont.	,,	11 58 28·5		,,
	,,	,,	,,	First cont.	Heliom.	11 52 44·1	12 1	F. B.
	,,	,,	,,	Bisection	,,	11 56 13·5		,,
	,,	,,	,,	Last cont.	,,	11 59 13·0		,,
10	,, 21	III	Trs. ingr.	First cont.	10-foot	12 45 32·7		L.
	,,	,,	,,	Last cont.	,,	12 58 50·5	13 2	,,
11	,, 29	II	Trs. egr.	First cont.	,,	11 39 47·0		,,
	,,	,,	,,	Last cont.	,,	11 49 15·4		,,
	,,	,,	,,	First cont.	Heliom.	11 40 26·4	11 49	F. B.
	,,	,,	,,	Bisection	,,	11 43 16·0		,,
	,,	,,	,,	Last cont.	,,	11 46 0·6		,,
12	,,	II	Shad. egr.	First cont.	10-foot	12 12 11·7		L.
	,,	,,	,,	Last cont.	,,	12 16 41·0	12 26	,,
13	,, 31	I	Occ. disapp.	First cont.	,,	12 3 12·2		L.
	,,	,,	,,	Bisection	,,	12 4 41·9		,,
	,,	,,	,,	Last cont.	,,	12 6 41·6	12 11	,,
	,,	,,	,,	First cont.	Heliom.	12 1 20·5		F. B.
	,,	,,	,,	Last cont.	,,	12 7 24·5		,,

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No.	Day and Year of Obs.	Satellite.	Phenomenon.	Phase of Phenomenon.	Instrument.	Oxford Mean Solar Time of Observation. h m s	Greenwich Mean Solar Time from *N.A.* h m s	Observer.
14	June 1 1875.	III	Ecl. reapp.	...	Heliom.	9 10 1·4	9 16 24·5	F. B.
15	„	I	Trs. ingr.	First cont.	„	9 10 52·3		„
	„	„	„	Bisection	„	9 12 7·1	9 18	„
	„	„	„	Last cont.	„	9 14 21·8		„
	„	„	„	Last cont.	10-foot	9 16 9·6		L.
16	„	I	Shad. ingr.	Last cont.	„	9 39 15·8		„
	„	„	„	Bisection	Heliom.	9 36 32·4	9 39	F. B.
	„	„	„	Last cont.	„	9 38 17·2		„
17	„	I	Trs. egr.	First cont.	10-foot	11 17 40·8		L.
	„	„	„	Last cont.	„	11 23 49·8		„
	„	„	„	First cont.	Heliom.	11 21 45·1	11 29	F B.
	„	„	„	Last cont.	„	11 24 59·6		„
18	„	I	Shad. egr.	First cont.	„	11 37 53·5	11 51	„
	„	„	„	Last cont.	10-foot	11 41 27·0		L.
19	„ 14	II	Ecl. reapp.	First seen	„	11 41 22·1		„
	„	„	„	Fully seen	„	11 41 56·5	11 48 27·6	„
	„	„	„	First seen	Heliom.	11 41 18·1		F. B.
20	July 3	III	Trs. egr.	Bisection	10-foot	10 57 57·4		L.
	„	„	„	Last cont.	„	11 7 55·8		„
	„	„	„	First cont.	Heliom.	10 51 16·5	11 10	F. B.
	„	„	„	Bisection	„	10 57 30·6		„
	„	„	„	Last cont.	„	11 2 59·7		„
21	„ 14	III	Ecl. reapp.	First seen	10-foot	9 3 36·9	9 12 8·0	L.
	„	„	„	Fully seen	„	9 4 11·8		„
22	Aug. 1	II	Trs. egr.	First cont.	„	9 0 22·2	9 5	„
	„	„	„	Last cont.	„	9 6 1·3		„
23	„	I	Occ. disapp.	First cont.	„	9 50 45·7	9 57	„
	„	„	„	Last cont.	„	9 53 35·2		„
24	„ 8	II	Trs. ingr.	First cont.	„	8 58 25·8	9 1	„
	„	„	„	Last cont.	„	9 0 30·5		„
25	„ 9	I	Trs. ingr.	First cont.	Heliom.	8 54 51·0	9 3	F. B.
	„	„	„	Last cont.	„	8 59 20·3		„
26	„ 10	II	Ecl. reapp.	First seen	„	8 39 50·9	8 46 59·5	„

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Notes.

No.

1 Cloudy.

2 The satellite very faint; cloudy.

3 The satellite was at least 20^s passing into the shadow, which was almost coincident with the limb of the planet.

4 The shadow was very faint, only seen at intervals, but the time noted is supposed to be very near the last contact; windy during the observation.

6 The satellite had been fading in brightness and was almost in contact with the planet when I last saw it.

8 Unsteady; at the last contact the satellite seemed to be on the planet and to jump off again.

10 The satellite at last contact moved along the limb of the planet for more than half an hour, the two limbs being in contact at 13^h 21^m; I did not think to look for the shadow till that time, when I was surprised to find it fully on the disk of the planet, with the limb just in contact. I thought every minute the satellite was coming off the planet, but on referring to the *Nautical Almanac* I found it would not do so for nearly two hours. Too tired to wait for the egress.

11 Uncertain. (L.)
The image of the planet very diffused. (F.B.)

12 Very doubtful. (L.)

13 Definition very bad. (L.)

14 Reappearance instantaneous.

16 Shadow very faint; probably the time noted is one minute too late. (L.)
The last contact is considered satisfactory. The times noted have been each diminished by five minutes. (F.B.)

17 The planet ill-defined; the satellite very faint. (Both observers.)

19 Very faint at reappearance. (L.)
Reappearance instantaneous, but the satellite faint owing to cloud. (F.B.)

20 Very unsteady and ill-defined; the satellite hung on the limb for some minutes after the last contact appeared to have taken place. (L.)
The planet was very tremulous, and the satellite seemed to hang on the limb for some minutes after last contact; at 11^h 12^m the satellite was quite detached from the limb. (F.B.)

22 The satellite faint.

24 Unsteady.

25 Cloudy during the observation; the planet was very badly defined and unsteady; the satellite seemed to jump away from it after the contact had taken place.

26 Cloudy during the observation; the satellite was very faint at the time of reappearance, and did not attain its usual brightness till one minute after.

The initials L., K., F.B., H.B. are those of Mr. Lucas, Mr. Keating, Mr. F. Bellamy, and Mr. H. Bellamy.

The instruments used were the heliometer with power of 200, and the 10-foot telescope with power of 160.

April 3, 1877.

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The Planet Vulcan. By the Rev. S. J. Perry.

The weather was exceedingly favourable here for the search for the intermercurial planet, and a careful watch was maintained throughout the whole of the 21st, 22nd, and 23rd of March. The spider-line micrometer was used with the 8-inch achromatic, and the Sun's image, projected on a screen of very smooth white cardboard attached to the eye-end of the telescope, had a diameter of $9\frac{1}{2}$ inches. An excellent driving clock is attached to the Equatoreal. On the 21st of March the Sun was observed from 9.30 A.M. till 6.3 P.M. G.M.T. Passing clouds obscured the image

	m		h	m		h	m
twice for	10	beginning at	2	49	and at	5	40
twice ,,	15	,, ,,	11	31	,, ,,	3	1
once ,,	23	,, ,,	12	25			

On March 22 the watch was kept up from 7.0 A.M. till 6.10 P.M., with only five breaks of continuity, viz. for

m		h	m
12	beginning at	10	34
14	,, ,,	11	48
17	,, ,,	10	5
20	,, ,,	2	8
and 24	,, ,,	12	25

On March 23, from 7.30 A.M. till 1 P.M., there was no interruption, but the Sun was obscured from 1 P.M. till $2^h\ 27^m$. Clouds also interfered for

m		h	m
10	beginning at	3	10
11	,, ,,	2	37
16	,, ,,	3	42

Observations were discontinued at 5.10 P.M. on account of the indistinctness of the image.

I have given above only the times when the Sun was obscured for at least 10^m; other lesser interruptions from small passing clouds were accurately noted, but it does not seem necessary to reproduce them here.

The definition on all three days was generally very good, and the atmosphere quite steady enough for good micrometric measurements. The faculæ around the double group of eight or nine spots on the western limb of the Sun, and the vast group of faculæ without any accompanying spot on the eastern side, were the only features that broke the monotony of the mottled surface during the whole period of observation.

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These observations, combined with any other set taken under equally favourable circumstances in this country, would suffice to establish the fact that *Vulcan* did not pass across the solar disk whilst the Sun was above our horizon from the 21st to the 23rd of March 1877.

Stonyhurst Observatory,
1877, *March* 24.

Report of Examination of the Sun's Disk at Guildown, Guildford, on 21st, 22nd, and 23rd March 1877, *for the suspected planet Vulcan, with a* 3¼*-in. Cooke Refractor. Huyghenian eye-pieces* 20 *and* 50. *Transit eye-piece about* 40. By J. Rand Capron, Esq.

Wednesday, 21st March 1877.

9 to 10. Frequent examinations. Sun spot, with group of much smaller ones, well seen near edge of Sun.
10 to 2. Very cloudy, occasional glimpses of Sun's disk through clouds.
2 to 4. Brighter, but still cloudy, allowing of examinations from time to time; practised photo-plates with larger telescope (8¼-inch reflector).

Thursday, 22nd March.

7.10. Sunrise in mist; small spot and faculæ seen on Sun's edge.
7.41. Less mist; spot plainer.
7.54. Mist breaking; Sun's limb sharp; spot and faculæ very distinct.
8.26. Still misty, but spot and faculæ well defined.
9.1. } Sun getting above mist, with bright disk.
9.33. }
10.12. }
10.47. Light misty clouds, but spot well seen.
11.0. } Sun quite bright.
11.35. }
Four Kennett plates taken between 9.30 and 11.30 with reflector.
11.52. Sun clouded.
12.20. Kennett plate, No. 5.
12.50. Snow flakes seen crossing the Sun's disk; none fell below.
12.57. Snowdrift continued, and clouds came up.
2.26. Curious cloud shadows overhead.
2.39. Sun's reappearance with bright disk.

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2.46. Kennett plate, No. 6.
2.52. Ditto „ 7.
3.30. Ditto „ 8.
3.34. Ditto „ 9.
} Small spot very close to Sun's edge.

Clouds and mist then came on.

5.25. Sun low; disk clear.

Friday, 23rd *March*.

6.58.
7.28.
7.55.
8.7.
8.47.
9.30.
10.0.
} Sharp frost; Sun rose in slight mist, which afterwards got denser; disk, however, well seen and quite clear.

10.18. Misty; fine Sun halo.
10.30. Disk clear.
11.0. Mist; wind freshening.
11.7. Disk clear.
11.38. Mist and wind; clouds coming up.
11.50. Clearer again.
12.33. Bright gleam; disk well seen and quite pure.
1.0. Glimpse among clouds.
1.45. Same.
1.48. Very bright glimpse.
2.52. Disk well seen through mist.
3.48. Same (with 20).
4.40. Sun in cloud and mist, but disk fairly seen with 20; wind high.
5.10. Fine Sun halo and Sun set in clouds.

Guildown, Guildford,
April 4, 1877.

Radiant Points of Shooting Stars. From Captain Tupman's unreduced Observations 1869–71.

By W. F. Denning, Esq., F.M.S.

(*Communicated by A. C. Ranyard, Esq., M.A.*)

The valuable observations of Shooting Stars by Captain Tupman in the years 1869–70–71, printed in 1873 for the British Association, contain a considerable number of meteor-paths that have not hitherto been reduced to their radiant points. Thus, between Jan. 21–Feb. 23 (1869) there are about 135, between Sept. 6–Oct. 13 (1869–71) 130, and between Dec. 12–23 (chiefly in 1869) 40 more, making about 300 altogether. These

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I have projected upon an 18-inch globe, and traced their several radiant centres, as specified in the subjoined list of 20 such positions well-ascertained, and supplementary list of 8 others less certainly indicated. I have annexed the positions of other observers which they confirm, and the comparison shows that there is a very fair accordance in most cases. It should be mentioned that these new determinations are purely independent of and separate from Captain Tupman's older positions (*Monthly Notices*, vol. xxxiii. p. 300), having been deduced from other meteors seen on other nights; in fact, they are founded on different materials, though gathered by the same hand, and the two sets of positions compared together in the table, each possess a distinct value, whether confirmatory or otherwise. The chief shower in the new list is No. 2 at α 236° δ +11° (near α *Serpentis*) for Jan. 21–Feb. 23, which this year I confirmed in the same place, and was well observed by Captain Tupman Feb. 13, 1869, at 237° +13°. Nos. 11 and 16 were also active radiants. No. 13 (Sept.) at 105°+53° is not included in existing catalogues, though I found a position at 90° +58° for Oct. (No. 29 of my list [1876] of radiants, *Monthly Notices*, vol. xxxvii. p. 105). The average of the two comes out at 98°+56°, which is suspiciously near the radiant point of Donati's Comet (100° +59° Sept. 8) as computed by Professor Herschel (*see* B.A. Report, 1875, p. 233)*. Capt. Tupman describes the meteors as "very swift," and I find his estimate of the apparent velocity of 9 of them averaged 0·2 sec. for 10 degrees. I found them bright and rapid, leaving streaks. The fourth radiant in the supplementary list verifies a new and prominent shower I saw from near ψ *Cygni* in January last, and since confirmed by Prof. Heis at 297°+53° Jan. 1–21.

The shooting stars employed in the determination of these radiants do not include the *whole* of Capt. Tupman's unreduced paths. Between Nov. 3–12, 1869, there are 80 such observations, and in August 1870 a few more; but I have not gone over them, inasmuch as the chief systems (*Leonids* and *Taurids* in the former, and *Perseïds* and *Cassiopeïds* in the latter) common to those periods are already thoroughly well known by the able investigations of Mr. Greg and Prof. Herschel, of the British Association Luminous Meteor Committee.

* Since the above was written, I have examined many hundreds of meteor-paths recorded between Aug. 15–Oct. 15 by Capt. Tupman, Mr. Lucas (Radcliffe Observatory, Oxford), the Italian observers (Schiaparelli, Denza, and others, 1872), and myself, and found 33 meteors agreeing to a radiant at 99° + 57° for September 1–15; while for the whole two months I have double that number from a general centre at 101° + 57°. The accordance of this new shower in date and position with the nodal passage of Donati's Comet is remarkable, though possibly accidental and showing no real affinity of origin. —W. F. D.

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List of 20 Radiant Points of Shooting Stars, deduced from Captain Tupman's Observations, 1869–71, not previously utilised.

	No. T. & D. 1877.	No. Tupman. 1873.	No. Greg. 1874.	Radiant-Point (T. & D. 1877). R.A. °	Dec. °	No. of ↓ s	Confirmations and Comparisons. T. (Tupman), G. and H. (Greg and Herschel), S. (Schmidt), S. and Z. (Schiaparelli and Zezioli), N. (Neumayer), H. (Heis), D. (Denning).
Jan. 21 to Feb. 23.	1	16–21	27	261	+ 4	8	T. 260° ±0°, Feb. 13; T. 266° +6° March 14–15.
	2	10	41	236	+11	20	T. 237 +13, Feb. 13; D. 236 +11, Feb.
	3	23	41	245	−22	9	T. 236 −13, March 2–3; T. 233 −18, March 7.
	4	11–17	44	209	−27	10	T. 204 −31, March 11–19; T. 202 −28, March 19.
	5	15	53	228	− 4	8	T. 230 −7, Feb. 13; G. and H. 227 −5, March–May.
	6	11–13	20	188	−26	8	T. 198 −22, Feb. 3–10; T. 180 −20, Feb. 8–10.
	7	6	8	204	−10	10	T. 202 −9, Feb. 13; T. 200 −10, March 2–3.
	8	17	44	218	−37	8	T. 217 −41, Feb. 22; N. 192 −38, March.
	9	2	28	174	+13	5	T. 175 +16, Feb. 3–10; G. and H. 175 +10, Feb.–March.
	10	10–25?	18	228	+29	11	G. and H. 233 +34, Jan. 28–29; D. 234 +32, Jan.–Feb.
Sept. 6 to Oct. 4 (chiefly).	11	78	138 164	59	− 9	13	T. 54 −14, Oct. 5-6; S. 55 −6, Sept. Eridanids.
	12	79	157	90	+19	8	T. 91 +18, Oct. 17; S. 93 +17, Oct. Orionids.
	13	...	...	105	+53	10	D. 90 +58, Oct. 14–15; new shower?
	14	68–69	114	50	+46	10	T. 45 +48, Sept. 5; S. 50 +48, Aug. 3–12.
	15	...	109	340	−14	7	S. 331 −13, Aug.–Sept.; N. 347 −11, Oct.
	16	93	150	28	+12	12	S. 22 +5, Aug.–Sept.; D. 27 +11, Sept.–Oct.
	17	75	115 117	54	+16	8	T. 62 +9, Sept. 14; S. 51 +14, Sept.
	18	82–80	155 153	113 98	+11 −10	10	T. 107 +12, Oct. 8 T. 92 −14, Oct. 12 } T. 101 ±0, Oct. 16.
	19	62	121	24	+36	8	T. 23 +36, Aug. 23; H. 23 +40, Oct.; S. & Z. 28 +36, Sept. 23;
	20	...	133	12	−12	7	G. and H. 17 −10, Sept.–Oct.; S. 9 −15, Aug.

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The above are the best positions. The following radiants were also clearly marked, though apparently more inactive, and therefore less reliable, than the preceding.

Date.	No. T.	No. G.	Radiant Point.		No. of ↙ s	Confirms
			°	°		
Feb.	...	54	180	+27	5	D. 186 +24, Feb. Distinct to G. 11?
Feb.	...	188?	120	− 5	4	D. 117 −7, Feb. New shower?
Feb.	2	5	168	+ 4	5	D. 168 +4, Feb. Allied to No. 9?
Jan.–Feb.	...	...	295	+51	5	D. 295 +53, Jan. (20 ↙ s). Fine new shower.
Sept.–Oct.	72	133?	76	+ 9	6	T. 75 +15, Sept. 22. Allied to No. 17?
Sept.	...	193	44	+77	5	G. and H. 47 +74, Sept.
Dec. 12–17	...	162	66	+69	5	D. 69 +66, Dec. Active shower. S. 66 +65, Nov.
Dec. 12–23	...	{180 183}?	53	+ 3	5	S. 55 +5, Dec.; Clark 57 +6, Dec. 10–12.

Slight radiation also from about 118° +29° (Oct.), 344° +54° (Dec.), and 33° +21° (Dec.).

Bristol, April 7, 1877.

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The Great Meteor of 1877, March 17. By Capt. G. L. Tupman.

A few minutes before 10 o'clock, G.M.T., on the evening of March 17, a meteor of very exceptional brilliancy was observed from the southern and western counties.

At Frome, 51° 14′ N., 2° 24′ W., it was seen by the Rev. G. Horner to begin 3° N. of *Pollux*, and terminate between γ and τ *Persei*.

At Cambridge, 52° 13′ N., 0° 6′ E., Mr. A. P. Trotter observed that its path and the line joining ε and ι *Orionis* bisected each other, the path being about twice as long as *Orion's* belt.

At Kensington, 51° 30′ N., 0° 12′ W., Mr. W. Thackeray saw it shoot from δ *Orionis*, downwards to the right, at an angle of 37° to the horizon.

At Gunnersbury, 51° 29′ N., 0° 17′ W., it appeared to come from *Gemini*, to pass over *Aldebaran*, and disappear below the *Pleiades* (*Nature*, March 22).

At Tetbury, 51° 38′ N., 2° 9′ W., Mr. E. C. Davis saw it disappear close to the *Pleiades*. Its path was inclined about 45° to the horizon, downwards and to the right.

At Rossall, 53° 55′ N., 3° 3′ W., it appeared to move from 3° north-west of α *Hydræ* to a point in R.A. $7^h\ 30^m$, Decl. 20° S. (*Nature*, March 29, and April 5).

At Brighton, 50° 49′ N., 0° 8′ W., Mr. W. Ainslie Hollis saw it disappear between the belt and the *Pleiades*, after describing a path of about 15°.

From these observations the radiant must have been very near R.A. 145°, N.P.D. 95°, or due *south*, at an altitude of 34°.

The point of disappearance is pretty accurately obtained at 29 statute miles over 5° 41′ N., 3° 4′ W. (near Pontypool). Combining, then, the Frome, Rossall, and Cambridge observations, as the most precise, the meteor first became visible 60 statute miles over 50° 59′ N., 3° 4′ W., or nearly over Taunton. This path satisfies the other descriptions within ordinary errors of observation. Its length was 59 statute miles. The duration was given as certainly about 3ˢ by Mr. Horner; 3ˢ by the observer at Gunnersbury; 4ˢ or 5ˢ by Mr. Hollis; 3ˢ by Mr. Ballard, at Banbury; and 2ˢ by another observer. The mean of these is 3ˢ·1, giving a relative velocity of 19 miles per second.

From the radiant point given above, the following parabolic elements of its orbit are deduced:—

	°
Ω	177·4
I	8·5
π	222·5
q	·850

Motion Direct

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whence the relative velocity is 13·3 statute miles per second, and the total duration 4½ seconds.

The size of the meteor was described as one-sixth the diameter of the Moon, at Banbury, and also at Brighton, and one-half at Bristol, but doubtless this large size was chiefly due to irradiation.

During the first half of its track, the meteor was like burning magnesium in appearance, then the colour became red, and lastly was vivid green. All along its track fiery ashes fell towards the Earth, and after the extinction of the principal part, a body of dark red sparks continued to fall for a short distance, as seen at Tetbury by Mr. Davis. Lady Portsmouth, driving near Basingstoke, 90 miles from the meteor, and facing west, "was startled by what appeared to be blue or bluish-green lights falling apparently in large flakes into a field on her left. Some seconds after, while the whole country was lighted up as if by the brightest possible lightning, a large red ball was seen travelling with comparative slowness on the right, over a field, into which it appeared to fall." From Waterford the meteor was seen to be double, one part closely following the other. This duplicity is not reported from any other place.

The meteor left little or no streak, and did not detonate, for several of the observers state that they listened for any noise.

The average of all the recorded times is $9^h\ 57^m$ G.M.T.

In Mr. Greg's List of Meteoric Radiants for 1874, No. 15 is R.A. 143°, N.P.D. 97°, from January 3 to March 16 (?). Such a radiant would be nearly stationary for a long time, as the meteors overtake the Earth obliquely; its duration to March 17 is therefore confirmed.

A curious instance of the inaccuracy with which meteor tracks are sometimes described is that of "J. M. W." in the *Times*, who says that "in London the meteor was two-thirds the size of the Moon *when overhead*." As a matter of fact, it was never within 65° of the zenith of London.

Two Mechanical Solutions of Kepler's Problem.

By Prof. C. Pritchard.

It is unnecessary to dilate upon the boon which would be conferred on observatories and computers, if the tiresomeness of the solution of this problem can be diminished. Every skilful computer has no doubt his own peculiar method, which to him by habit facilitates the work more or less; perhaps that proposed by Dr. de Gasparis in the last Number of the *Monthly Notices* will be among the best. I venture to submit to the Society two mechanical methods of solution, which in the course of less than two minutes landed me just at the point reached in the ex-

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ample given by Dr. de Gasparis above. The principle is as follows; but the description, if full, would occupy more time than the practical working of an actual case. Suppose a lath AB (fig. 1) divided into inches and tenths, and that two *trammels* slide upon it, accurately fitted. Each inch is intended to represent the length of an arc of a circle of one degree, the radius of which, therefore, is 57·296 inches. This subdivision into tenths is equivalent to one hundredth of an inch by estimation, and admitting of no error of that amount, i.e. no error amounting to 36″. The other implement required is a good carpenter's rule (fig 2) with a good hinge, with a line on each of the two laths, diverging from the middle of the hinge as the origin, and each line divided into the line of natural sines OC, OD to one tenth of a degree, and to the same radius as the lath. This implement forms, in fact, what is technically called a *sector*. Suppose the question were: "Having given M, the mean anomaly, = 15°·676, and the eccentricity $e = ·5$, required the eccentric anomaly u."

The well-known form is $u = M + e \sin u$.

Inasmuch as the sine of 30° is one-half of the radius, open the two legs of the jointed rule, or *sector*, until from 30° to 30° spans $·5 \times \sin 30°$, or one-fourth of 57·296 inches, i.e. 14·324 inches. It follows from the construction that, in the sector thus opened, from 10° to 10° will span $\frac{1}{2} \sin 10°$, and from 20° to 20°, $\frac{1}{2} \sin 20°$ &c., and so on for all corresponding divisions of the two lines of natural sines. The sector being thus prepared, take the divided lath and set one trammel (A) at the mean anomaly 15·68 inches, and let the other trammel (B) be moved backwards and forwards until a division (u) is found on it, such that from A to B will span across the space between the same identical divisions u to u on the opened sector; $u°$ is then the eccentric anomaly sought. In this example $u°$ turns out to be 30° *quam proximè*.

The reading of this description of the *modus operandi* has probably occupied more time than the working of an actual instance when once understood. The truth also of the method is obvious. For, from O to A on the lath is made to equal the mean anomaly, and from A to B, found as above, is $e \sin u$; consequently from O to B, i.e. the reading of B on the divided lath, is $OA + AB = M + e \sin u = u$.

Practically, my own implements are, for convenience, constructed with a radius of 20 inches, and as these land us at once within 1″·5 of the true value of u, it is quite near enough for the application of the differential formula, finally completing the value of u. Of course, if the scales were absolutely divided, and could be so read, the solution above obtained would be strictly accurate. But supposing the reading thus obtained to be u_0, and the correct value $u_0 + \delta u$, then

$$\delta u = \frac{M + e \sin u_0 - u_0}{1 - e \cos u_0}.$$

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Fig. 3.

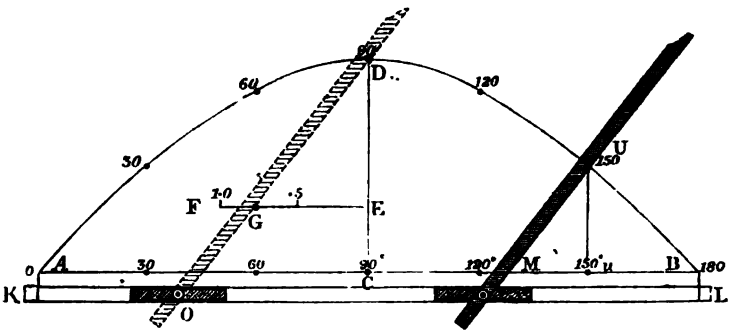


Fig. 4.

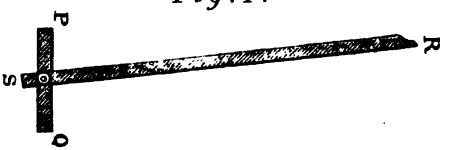


Fig. 1.

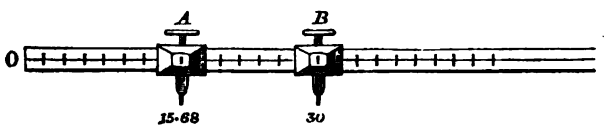
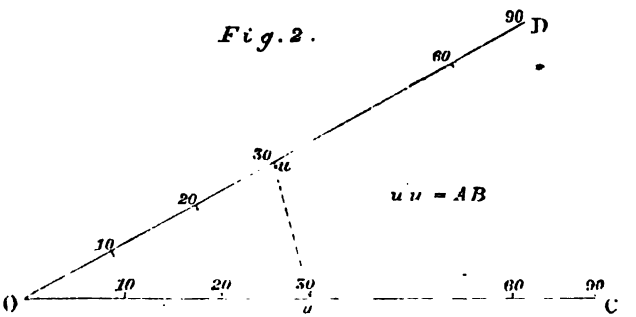


Fig. 2.



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I will merely add that it is obvious that the length of the divided lath may be considerably curtailed in practice by a double *numbering* of the divisions, the upper numbering commencing (say) at 80° and proceeding to 180°, and the lower commencing with 0° and proceeding to 90°..

Other minor conveniences will suggest themselves to any computer of ingenuity, and the author of this paper will be happy to give any further assistance or description required.

Besides the preceding method, I have completed another contrivance, which is, perhaps, equally effective, and even somewhat easier to use, inasmuch as there is nothing *tentative* in its application. The germ of the thought will be found in the *Monthly Notices* a few years back, where Mr. Proctor refers to a method proposed by Prof. Adams, and which he there elaborates at some length, but which practically cannot well be utilised in computations. (See *Monthly Notices*, April 1873.)

The machine as used in the Oxford University Observatory is as follows:—

On a flat board is carefully stretched a sheet of paper, divided into squares of one inch, and subdivided again into squares of twentieths or thirtieths of inches.

This paper (or others like it) is supplied by Messrs. Waterlow, of Birchin Lane, London, and no doubt can be procured elsewhere.

From A to B is 45 inches (fig. 3), divided into 180 equal parts by means of the engraved lines. Each inch represents four degrees.

On this as base is erected the curve of sines so that CD, the sine of 90°, is equal to the radius, i.e. to the length of the arc of 57°·296, or 14·324 inches. DE is taken = 10 inches, and EF, perpendicular to it, is also 10 inches, divided by the engraved lines into twentieths of an inch. Below AB is a groove, KL, strictly parallel to the base AB. Into this groove is placed the slider PQ (fig. 4) carrying at its middle a thin lath with a perfectly straight bevelled edge, ROS, which, by means of a thumbscrew, moves round O, and can be thereby fixed at any inclination to PQ. The curvilinear part ADB is numbered correspondingly to the base ACD for every 10 degrees, and is capable of being read, by means of the engraved lines and estimation of subdivisions, to 2′ of arc.

The application of this simple implement to an actual example is easy and rapid.

For instance, let the mean anomaly M = 124°·933, e = ·875, and let it be required to find the eccentric anomaly U. For this purpose place the slide in the groove, and move the lath round O until the straightedge passes precisely against D and G, where the reading of G on the small scale EF is the eccentricity —here = 8·75 inches. Then clamp the lath by means of the thumbscrew; and slide it until its edge stands precisely against the mean anomaly M on the base, where the reading is here 124°·933 as near as estimation admits. Then the reading

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U, where the straightedge cuts the line of sines, is the eccentric anomaly sought. In this instance U reads 150° *quam proxime*, but probably not exactly. Whatever the reading is, it can be treated in the usual way as a close approximate solution; and from it exactness to any amount of precision may be obtained by the application of the differential formula above. It will be observed that the only novelty here claimed consists in the application of the slider in the groove, thus obviating any drawing of parallel lines; and in the adaptation of the small scale EF, thus furnishing an immediate means of placing the straightedge at the proper inclination to the base ACB required by the eccentricity *e*.

This machine admits of home manufacture: and either of the two solves the question of Kepler's Problem with sufficient accuracy for double-star orbits without further computation.

The demonstration is obvious. For

$$Mu = Uu.\cot DGE = \frac{GE}{ED}\cdot Uu = e \sin Au;$$

hence

$$Au = AM + Mu = M + e \sin Au.$$

that is

$$eU = M + e \sin U.$$

On the Inequality in the Moon's Longitude discovered by Prof. Newcomb. By E. Neison, Esq.

In my communication to the Society entitled "On the Lunar Perturbations arising from the Planet *Jupiter*" (*Monthly Notices*, xxxvii p.248), reference was made to a new periodical term in the Moon's Longitude of the form

$$\delta v = -1''{\cdot}163 \sin\{(2-2m_1-c)\,nt+f-2f_1+A\},$$

where $(nt+f)$ denotes the mean longitude of the Moon, $(cnt+f-A)$ is the mean anomaly of the Moon, and (n_1nt+f_1) represents the mean longitude of *Jupiter*. Reducing the argument of this term to a form depending on the mean anomaly of the Moon $(=g)$ and a term increasing directly with the time, it becomes

$$\delta v = -1''{\cdot}163 \sin\{g+20°{\cdot}85\,(Y-1855{\cdot}76)\},$$

or, what is the same thing,

$$\delta v = +1''{\cdot}163 \sin\{g+20°{\cdot}85\,(Y-1864{\cdot}4)\}.$$

In his communication to the Society, "On a hitherto unnoticed Inequality in the Longitude of the Moon" (*Monthly Notices*, June 1876, p. 358), Prof. Newcomb describes a new empirical term discovered by himself, and which is

$$\delta v = -1''{\cdot}5 \sin\{g+N°-90°\},$$

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where

$$N = 163^\circ\cdot2 + 21^\circ\cdot6\,(t - 1868\cdot5).$$

Reducing this to the same form as the theoretical term, it becomes

$$\delta v = -1''\cdot5 \sin\{g + 21^\circ\cdot6\,(Y - 1865\cdot1)\}.$$

The two terms are therefore identical, with the exception of Prof. Newcomb's empirical term having the greater coefficient.

This fact entirely confirms the discovery made by Prof. Newcomb, and is obviously entirely unaffected by the existence of any discrepancy between the corrections to Hansen's Tables deduced by Prof. Newcomb and the observed corrections such as Capt. Tupman has made out.

Owing to an accidental error, which has just been detected, towards the end of the numerical reduction of the analytical results, the values of the co-efficients of the inequalities due to *Jupiter* given in the March number of the *Monthly Notices* are not quite accurate. They should be

$$\delta\frac{1}{r} = -0''\cdot578 \cos\{(2 - 2m_1 - c)\,nt + f - 2f_1 + A\}$$
$$-0''\cdot003 \cos\{(2 - 2m_1 - 2c)\,nt - 2f_1 + 2A\},$$

and

$$\delta v = -1''\cdot163 \sin\{(2 - 2m_1 - c)\,nt + f - 2f_1 + A\}$$
$$+2''\cdot200 \sin\{(2 - 2m_1 - 2c)\,nt - 2f_1 + 2A\}.$$

Comet 1877, *II.*, *discovered by Professor Winnecke April* 5.

(*Extract of a Letter from Prof. Winnecke to Mr. Hind*).

"The new Comet was observed here by me on April 5, 6, and 7. From these observations Herr Hartwig has calculated the orbital elements:—

T	April 18·1741 Berlin Time.			
	°	′	″	
$\pi - \Omega$	65	51	21	
Ω	317	51	18	(1877·0)
i	123	17	18	
log q	9·96767			

For the middle observation $\Delta\lambda = +2''\cdot0$, $\Delta\beta = -10''\cdot0$ (C − O).

"From these elements Dr. Schur has deduced the following Ephemeris:—

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12h Berlin	R.A. h m s	δ ° ′	log r	log Δ
April 5	22 7 42	+14 41·9	9·9802	0·1458
„ 9	22 10 56	19 33·1	9·9736	0·1149
„ 13	22 15 5	25 8·9	9·9694	0·0831
„ 17	22 20 34	31 36·4	9·9677	0·0518
„ 21	22 28 11	39 0·0	9·9686	0·0226
„ 25	22 39 20	47 18·5	9·9719	9·9982
„ 29	22 56 53	56 19·4	9·9777	9·9812
May 3	23 27 48	65 33·2	9·9857	9·9742
„ 7	0 31 40	+74 0·3	9·9955	9·9783

"The analogy of these elements with those of the Comets 1827 II. and 1852 II. is great, and the circumstance of the intervals being nearly equal gives it a certain significance."

The Comets of 1877. By Professor C. Pritchard.

Borelly's Comet I.

The Ephemeris of Borelly's Comet was sent to me at the Oxford University, by the Astronomer Royal, on the 20th of February, and was observed here on the same night. Subsequently to this it has been observed 14 times, and of these observations nine are completely reduced; the remaining six await the co-ordinates of the comparison stars, which have been kindly promised by the Astronomer Royal. When this telescopic comet was first seen in our large refractor of 12¼ inches aperture it appeared to be sufficiently bright for observation with an aperture of probably 3 inches, and was, I believe, actually observed by Captain Tupman, at the Royal Observatory, with a telescope of that aperture. On the 30th March the comet was observed for the last time in our great telescope with considerable difficulty; on the 4th April it was too faint to be certainly seen in our instrument, and it is now probably out of sight. The whole series of observations will be presented to the Society as soon as the reduction is complete.

D'Arrest's Comet.

D'Arrest's Comet has here been looked for in vain, in the places assigned for it in Leveau's Ephemeris. The twilight and the Moon may render observations of this interesting body very difficult for some time to come.

Winnecke's Comet II.

From an observation made on the 5th of this month at Strasburg, and telegraphed to this Observatory by the Astro-

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nomer Royal, together with two observations made here on the nights of the 7th and 11th inst., the following *preliminary* Elements and Ephemeris have been computed:—

T = April 19·98193 G.M.T.

π = 250° 48′ 27″
Ω = 318 2 21 } Apparent Equinox, Ap. 7.
i = 57 55 2

$\log q$ = 9·9748138

Motion retrograde.

Ephemeris for Greenwich Mean Midnight.

	R.A. h m	δ ° ′	log Δ
April 12	22 14·1	+23 29	
			0·1024
13	22 15·3	24 55	
14	22 16·5	26 24	
			0 0869
15	22 17·8	27 56	
16	22 19·2	29 31	
			0·0717
17	22 20·7	31 9	
18	22 22·3	32 51	
			0·0568
19	22 24·1	34 36	
20	22 26·0	36 25	0·0425

This comet as first seen here on the 7th inst. was tolerably conspicuous, with considerable condensation, approaching to a planetary nucleus, the whole nebularity, in early twilight, having a diameter of about a minute and a half. On the 11th inst., without apparent alteration in form or brightness, it was distinctly visible in a 2-inch telescope, and from the character of its orbit may probably become visible to the naked eye about the end of the month.

1877, *April* 13.

P.S.—Subsequently to the reading of this paper another Comet was discovered by Mr. Swift, of Rochester, U.S., on April 11, and, independently, on April 14, by M. Borelly, at Marseilles, in the Constellation *Cassiopeia*. This Comet was observed here on the 16th, and on every favourable opportunity since. The observations will in due course be communicated to the Society.

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Note on a Deviation of the Plumbline. By M. Otto Struve.

It may be interesting to mention that extraordinary deviations of the plumbline have been discovered in the Crimea by M. Kortazzi, Director of the Observatory, Nicolayeff. For Falta, $\Delta\phi = +29''$, $\Delta\lambda = -28''$; for Sevastopol, $\Delta\phi = +5''$, $\Delta\lambda = +21''$. We are about to examine the matter accurately. As Falta has been a successful *Venus* station, the deviation may possibly affect the future computation of its parallax. Of course the geodetic co-ordinates should be used as deduced from undisturbed points, together with Greenwich time of transit corresponding to the deviated plumbline.

10*th March* 1877.

The Johnson Memorial Prize.

(Extracted from the *Oxford University Gazette* of January 23, 1877.)

The Trustees of the Johnson Memorial Prize for the encouragement of the study of Astronomy and Meteorology propose the following subject for an essay:—

The History of the Successive Stages of our Knowledge of Nebulæ, Nebulous Stars, and Star Clusters, from the time of Sir William Herschel.

The prize is open to all members of the University of Oxford, and consists of a gold medal of the value of ten guineas, together with so much of the dividends for four years on 338*l.* Reduced Annuities as shall remain after the cost of the medal and other expenses have been defrayed.

Candidates are to send their essays to the Registrar of the University, under a sealed cover marked 'Johnson Memorial Prize Essay,' on or before March 31, 1879, each candidate concealing his name, distinguishing his essay by a motto, and sending at the same time his name sealed up under cover with the same motto written upon it.

Correction.—*Monthly Notices*, vol. iii. p. 205, Feb. 1877.—An error of some magnitude in the "Report on the Progress of Meteoric Astronomy" (four last lines and the note att he bottom of the page) requires to be corrected. The date there given of an aërolite said to have fallen at Louisville, Kentucky, U.S., on the 8th, should have been on the 18th of July 1876. No coincidence of the date accordingly occurred (such as is mentioned in the note at that place) with that of the large meteor seen in Indiana, U.S., on the 8th July 1876.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. *May* 11, 1877. No. 7.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

William Morris Beaufort, Esq., 18 Piccadilly, and Athenæum Club,

was balloted for and duly elected a Fellow of the Society.

Extracts from Letters received by the Astronomer Royal, relating to the Search for the supposed Intra-Mercurial Planet.

The post has now brought letters in reply to some of the telegrams which were addressed to distant stations requesting a search for the supposed Intra-Mercurial Planet. The following is the substance of the information conveyed.

From R. N. Pogson, Esq., Government Observatory, Madras.

"Eye-observations were made at nearly every ten minutes on March 21, 22, 23, and fourteen photographs were taken on March 22. *Vulcan* was not seen."

From Charles Todd, Esq., General Post Office, Adelaide.

"The weather was excessively bad, with clouds and thunderstorm; $3\frac{1}{2}$ inches of rain fell in Adelaide, and 5 or 6 inches in the neighbourhood. Observations were attempted, but *Vulcan* was not seen."

From R. L. J. Ellery, Esq., The Observatory, Melbourne.

"The weather was fine, the Sun was observed almost uninterruptedly, and numerous photographs were taken. No appearance of *Vulcan*."

Royal Observatory, Greenwich,
1877, *April* 7.

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Sun Spot Drawings of the Rev. Frederick Howlett.

In the short account given in the May number of the *Monthly Notices* for 1876 of the volumes of Sun Spot Drawings which have been presented to the Library of the Astronomical Society by the Rev. F. Howlett, it should have been mentioned that a large number of the drawings of the Sun's disk are marked with a small line and figures, indicating the distance of the west point of the Sun's limb from the vertex or highest point of the Sun above the horizon at the time of observation.

The image of the Sun was projected on a screen on which was a graduated circle with 0° at the vertex, 90° being to the right hand, 180° at the bottom, and 270° to the left hand. A small spot, or some easily recognised detail of an irregular large spot or large group, was brought to the centre of the graduated circle, which was marked by a small pin-hole in the cardboard screen. The telescope was then left in position, and as the Sun's image was carried off the screen by the Earth's motion, the angular distance from the vertex at which the spot or detail which had been brought to the centre passed across the circumference of the graduated circle was noted and entered upon the drawing. The position of a small line which has been marked upon the edge of the drawings of the Sun's disk depends on the assumption, that the highest point upon the page of the book accurately corresponded with the highest point of the Sun's image as seen by projection on the screen.

The horizontal and vertical co-ordinates of spots given in some of the drawings were made with an eye-piece in the focus of which was a thin slip of semi-transparent mother-of-pearl, graduated into divisions $\frac{1}{100}$th of an inch apart, every 5th and 10th gradation being made more conspicuous for the purpose of easily counting them. At right angles to the scale, and nearly bisecting the field of view, was stretched a fine wire, which was first placed vertically, so as to bisect the image of the Sun; the mother-of-pearl scale was now brought up to the centre of the spot, and the number of gradations to the right or left of the wire were counted; the eye-piece was then turned so that the wire when in a horizontal position bisected the Sun's image, and the mother-of-pearl scale brought again to the spot, and the number of gradations above or below the wire counted as before. It will be seen that these distances do not correspond to the horizontal and vertical ordinates of Pastorff's drawings, in which the distances measured horizontally and vertically were measured from the limbs of the Sun.

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Note on the alleged Fall of an Aërolite at Supino, Italy.

By Padre Secchi.

(*From a Letter to E. Dunkin, Esq., F.R.S.*)

In the *Monthly Notices*, vol. xxxvii., No. 4, February 1877, page 205, I find indicated a fall of a meteor on September 4, 1875, 4 P.M. local time, at Supino, near Rome, in the province of Frosinone. As I am well acquainted with the particulars of this event, I can assure you that this is an equivocation, and a very great mystification. I have had the stone in my hand, and there is not the least appearance of the classical crust or varnish of aërolites, nor of the composition of the meteoric stones I have seen and so attentively examined at the British Museum and at the Jardin des Plantes.

It is not difficult to understand from the circumstances attending the fall how this equivocation has originated. It was a very stormy evening, and an electrical explosion took place, which traversed a gallery in the house of the parish priest. A nail was pointed out against which the flame of the alleged aërolite struck. At the same time some noise of a fallen body was heard, and a stone not previously existing in that court was found; hence the conclusion that a meteor had fallen at Supino. A German assistant to a Professor at the University went immediately to Supino and gave fifty francs for a piece of the stone. The owner of the house thought that he had really received *from the heavens* a treasure to provide the means for a dotation to a nephew on his approaching marriage, and, as this was near, he asked fabulous sums for the remainder of the stone. Prof. De Rossi visited the place and was persuaded that the gallery could not have been traversed by the stone, but only by the lightning. No hole of any depth was found in the place where the stone fell. He brought it to Rome; and when I saw it we were convinced that it was only a piece of volcanic pumice, which is frequently found in that district, an extinct volcano being at no great distance.

The fall may be explained thus. In this country it is customary to place stones on the tiled roofs of the houses, to prevent the tiles from being blown away by the winds. A volcanic stone was probably on the roof, and the lightning struck against it as a more conducting material, and threw it into the court. This explanation, which is very simple, is very probable; the noise heard was not that of a meteor, but that of the thunder storm.

I have considered it my duty to inform the Society of the above facts, to avoid mystification.

Rome, April 19, 1877.

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On an Elliptic Function Solution of Kepler's Problem.

By J. W. L. Glaisher, M.A., F.R.S.

§ 1. In a paper recently published by the German Astronomical Society,* Dr. Hugo Gyldén has applied the Theory of Elliptic Functions to the solution of Kepler's Problem in the following manner:—

Writing the equations in the form

$$\tan\tfrac{1}{2}f = \sqrt{\left(\frac{1+e}{1-e}\right)}\tan\tfrac{1}{2}\mathrm{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\mathrm{M} = \mathrm{E} - e\sin\mathrm{E} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)\dagger$$

(where M, $= nt + c$, is the mean anomaly, E the eccentric anomaly, and f the true anomaly) Dr. Gyldén takes $\frac{1}{2}$E equal to the amplitude of an elliptic integral—viz. he puts

$$\tfrac{1}{2}\mathrm{E} = \mathrm{am}\, v,$$

the modulus k being given by the equation

$$k = \sqrt{\left(\frac{2e}{1+e}\right)} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (3)$$

so that $k' = \sqrt{\left(\frac{1-e}{1+e}\right)}$, and thus the equations (1) and (2) become, on writing $\frac{1}{2}f = \mathrm{am}\, u$,

$$\mathrm{coam}\, u = 90^\circ - \mathrm{am}\, v \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (4)$$

$$\mathrm{M} = 2\,\mathrm{am}\, v - e\sin(2\,\mathrm{am}\, v) \quad . \quad . \quad . \quad . \quad . \quad (5)$$

The quantities r, x, y are also readily expressible in terms of elliptic functions of u or v.

The equation (5) may be written

$$\mathrm{M} = 2\,\mathrm{am}\, v - 2e\,\mathrm{sn}\, v\,\mathrm{cn}\, v$$

$$= 2\,\mathrm{am}\, v + \frac{2e}{k^2}\frac{d^2}{dv^2}(\mathrm{am}\, v) \quad . \quad . \quad . \quad . \quad . \quad . \quad (6)$$

and from the Theory of Elliptic Functions we know that

$$2\,\mathrm{am}\, v = 2\eta + \frac{4q}{1+q^2}\sin 2\eta + \frac{1}{2}\frac{4q^2}{1+q^4}\sin 4\eta + \&c. \quad . \quad . \quad (7)$$

* "Zur Auflösung des Kepler'schen Problemes." *Vierteljahrsschrift der Astronomischen Gesellschaft*, t. x. (1875), pp. 285-296.

† I have slightly altered the notation: Dr. Gyldén writes (2), $g = \epsilon - e\sin\epsilon$.

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η being written in place of $\frac{\pi}{2K}v$, so that, taking account of the value of e given by (3), the equation (6) becomes

$$\begin{aligned} M = 2\eta &- \left[\frac{4\cdot 1^2}{1+k'^2}\left(\frac{\pi}{2K}\right)^2 - 1\right]\frac{4q}{1+q^2}\sin 2\eta \\ &- \frac{1}{2}\left[\frac{4\cdot 2^2}{1+k'^2}\left(\frac{\pi}{2K}\right)^2 - 1\right]\frac{4q^2}{1+q^4}\sin 4\eta \\ &- \frac{1}{3}\left[\frac{4\cdot 3^2}{1+k'^2}\left(\frac{\pi}{2K}\right)^2 - 1\right]\frac{4q^3}{1+q^6}\sin 6\eta \\ &- \text{\&c.} \quad \ldots\ldots\ldots\ldots\ldots\ldots \quad (8) \end{aligned}$$

This equation is used to replace (2), viz.—given e we can calculate k from (3), then q from k, by known elliptic function formulæ, and $\log\frac{2K}{\pi}$ from q, by means of the equation

$$\frac{2K}{\pi} = (1 + 2q + 2q^4 + 2q^9 + \text{\&c.})^2.$$

We thus obtain the numerical values of the coefficients of $\sin 2\eta$, $\sin 4\eta$, &c., in (8), and can determine by successive approximation the value of 2η, corresponding to a given value of M, and thence from (7), the value of 2 am v, that is, of E.

§ 2. Thus, in this method, the expression (2) is replaced by the two formulæ (7) and (8), which, though more complicated, are such that the convergence of the successive approximations is more rapid; in fact, the simplicity and slow convergence of (2) are exchanged for the greater complication and quicker convergence of (7) and (8). Of course, the question of whether the exchange is an advantageous one can only be definitively settled by careful numerical comparisons.

In what follows I propose to discuss the general nature of such an elliptic function solution of the problem as Dr. Gyldén proposes, and to examine, in particular, what value should be assigned to the modulus in order that the convergence of the approximations may be rendered as rapid as possible. It will be shown also that the calculation of the coefficients in (7) and (8) may be much facilitated; and some remarks upon the question of the practical utility of the method will be found in § 13.

§ 3. It is readily seen that the solution of the equation

$$x = a + n\phi(x),$$

where n is small, by successive approximation is equivalent to expanding x in powers of n by Lagrange's theorem, viz.:—

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First approximation $x = a$;

Second ,, $x = a + n\phi a$;

Third ,, $x = a + n\phi(a + n\phi a)$

$= a + n\phi a + n^2\phi a\phi' a +$ &c.;

Fourth ,, $x = a + n\phi(a + n\phi a + n^2\phi a\phi' a)$

$= a + n\phi a + n^2\phi a\phi' a + n^3\phi a\,(\phi' a)^2 + \frac{1}{2}n^3(\phi a)^2\phi'' a +$ &c.

$= a + n\phi a + \frac{n^2}{1.2}\frac{d}{da}(\phi a)^2 + \frac{n^3}{1.2.3}\frac{d^2}{da^2}(\phi a)^3 +$ &c.

so that the rth approximation differs from the truth by a quantity of the order n^r; and by the diminution of n the rapidity of the convergence of the approximation is very considerably increased.

The object in view is thus to render the coefficients of $\sin 2\eta$, $\sin 4\eta$, $\sin 6\eta$, &c., as small as possible, without unduly increasing the number of terms that must be included.

Resuming the equations (6) and (7), we have

$$2\,\mathrm{am}\,v = 2\eta + \frac{4q}{1+q^2}\sin 2\eta + \frac{1}{2}\frac{4q^2}{1+q^4}\sin 4\eta + \&c.$$

$$2\left(\frac{k\mathrm{K}}{\pi}\right)^2 \mathrm{sn}\,v\,\mathrm{cn}\,v = \frac{4q}{1+q^2}\sin 2\eta + 2\frac{4q^2}{1+q^4}\sin 4\eta + \&c.$$

so that, writing for brevity

$$\mathrm{R} = \left(\frac{\pi}{k\mathrm{K}}\right)^2,$$

we have

$$\begin{aligned}\mathrm{M} &= 2\,\mathrm{am}\,v - 2e\,\mathrm{sn}\,v\,\mathrm{cn}\,v\\ &= 2\eta - \left(\mathrm{R}e - 1\right)\frac{4q}{1+q^2}\sin 2\eta\\ &\quad - \left(2\mathrm{R}e - \frac{1}{2}\right)\frac{4q^2}{1+q^4}\sin 4\eta\\ &\quad - \left(3\mathrm{R}e - \frac{1}{3}\right)\frac{4q^3}{1+q^6}\sin 6\eta\\ &\quad - \&c. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (9)\end{aligned}$$

or, as we may write it,

$$\begin{aligned}\mathrm{M} &= 2\eta - (\mathrm{A}_1 e - \mathrm{B}_1)\sin 2\eta\\ &\quad - (\mathrm{A}_2 e - \mathrm{B}_2)\sin 4\eta\\ &\quad - (\mathrm{A}_3 e - \mathrm{B}_3)\sin 6\eta\\ &\quad - \&c. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (10)\end{aligned}$$

where

$$\mathrm{A}_n = n\mathrm{R}\frac{4q^n}{1+q^{2n}}, \quad \mathrm{B}_n = \frac{1}{n}\frac{4q^n}{1+q^{2n}}.$$

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For values of the modular angle that are not very considerable q is very small, and therefore B_1 is small, and as we know that the series

$$A_1 \sin 2\eta + A_2 \sin 4\eta + A_3 \sin 6\eta + \&c.$$

is the sine of the series

$$2\eta + B_1 \sin 2\eta + B_2 \sin 4\eta + \&c.,$$

it is clear that, for values of the modular angle that are not near 90°, A_1 will not differ much from unity; but the following numbers show at a glance the variation of A_1 and q as the modular angle increases.

k	A_1	q
sin 15°	0·99991	0·00433
sin 30°	0·99839	0·01797
sin 45°	0·99071	0·04321
sin 60°	0·96399	0·08580
sin 75°	0·87701	0·16303

Thus, for values of the modular angle less than 45°, the value of A_1 does not differ from unity by the one-hundredth part, and the value of q is less than $\frac{1}{23}$. Speaking roughly, the values of A_n and B_n are respectively equal to $q\,A_{n-1}$ and $q\,B_{n-1}$, so that for all values less than 60° the series (9) is very convergent, while A_1 differs very little from unity. The method would evidently not be a suitable one if the angle were as large as 75°, and in what follows the angle is supposed not to exceed 50° or 60°.

§ 4. The coefficient of sin 2η in (10) can be made to vanish if the modulus k be so chosen that $A_1 e = B_1$; that is, taking $A_1 = 1$, if approximately

$$e = \frac{4q}{1+q^2} = 4q \text{ nearly};$$

or

$$q = \frac{1}{4} e.$$

In order to obtain exactly the order of the first term when q has this value, it is necessary to use the expression for $\left(\frac{kK}{\pi}\right)^2$ in terms of q, viz.

$$\left(\frac{kK}{\pi}\right)^2 = \frac{4q}{1-q^2} + \frac{12q^3}{1-q^6} + \frac{20q^5}{1-q^{10}} + \&c.$$

$$= 4q\,(1 + 4q^2 + 6q^4 + \&c.);$$

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whence, rejecting powers of q above cubes,

$$R = \frac{1}{4q(1+4q^2)} = \frac{1-4q^2}{4q};$$

so that, when $e = 4q$,

$$Re = 1-4q^2$$

and the coefficient of $\sin 2\eta$

$$= 4q\left(\frac{1-4q^2}{1+q^2} - \frac{1}{1+q^2}\right)$$

$$= -16q^3 = -\frac{1}{4}e^3;$$

and thus, retaining only the terms of the highest order in e in each coefficient, the equation (10) becomes

$$M = 2\eta + \frac{1}{4}e^3 \sin 2\eta - \left(2-\frac{1}{2}\right)\frac{1}{4}e^2 \sin 4\eta - \left(3-\frac{1}{3}\right)\frac{1}{4^2}e^3 \sin 6\eta$$

$$-\left(4-\frac{1}{4}\right)\frac{1}{4^3}e^4 \sin 8\eta - \&c.$$

$$= 2\eta + \frac{1}{4}e^3 \sin 2\eta - \frac{3}{8}e^2 \sin 4\eta - \frac{1}{6}e^3 \sin 6\eta - \frac{15}{256}e^4 \sin 8\eta - \&c.;$$

so that M differs from 2η only by quantities of the order e^2.

The value of q for which the coefficient of $\sin 2\eta$ exactly vanishes is, as is evident at sight from (9), given by the equation

$$e = \frac{1}{R} = \left(\frac{k\mathrm{K}}{\pi}\right)^2,$$

that is, by

$$e = 4q + 16q^3 + 96q^5 + \&c.,$$

giving

$$q = \frac{1}{4}e - \frac{1}{16}e^3 + \frac{21}{512}e^5 - \&c.$$

and therefore $q = \frac{1}{4}e$ is a very close approximation.

§ 5. The special point of advantage that the elliptic function solution offers is now apparent, viz. in the equation $M = E - e\sin E$ we replace E and sin E by two series, the former being of the form $2\eta + B_1 \sin 2\eta + B_2 \sin 4\eta + \&c.$, and the latter of the form $A_1 \sin 2\eta + A_2 \sin 4\eta + \&c.$, but we have at our disposal a certain quantity (the modulus) on which the values of A_1, $A_2 \ldots$ B_1, $B_2 \ldots$ depend, and we can so select it that the coefficient of $\sin 2\eta$ in the combined expression for M may be very small, and also the coefficients of the succeeding terms.

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In his solution Dr. Gyldén has not chosen his modulus with this view, but, as mentioned in § 1, he takes

$$k = \sqrt{\left(\frac{2e}{1+e}\right)},$$

this value being assigned to k, not in order that the coefficients in (10) may be rendered as small as possible, but that the equation (1), viz.—

$$\tan\tfrac{1}{2}f = \sqrt{\left(\frac{1+e}{1-e}\right)}\tan\tfrac{1}{2}\mathrm{E}$$

may, by comparison with the elliptic function relation

$$k'\tan\mathrm{am}\,u = \frac{1}{\tan\mathrm{coam}\,u},$$

be converted into the relation

$$\mathrm{coam}\,u = 90^\circ - \mathrm{am}\,v.$$

Thus the object in view in determining the modulus was to obtain an analytical transformation of the problem of two bodies; but if the solution of Kepler's problem be alone considered—and to this Dr. Gyldén restricts himself in the numerical examples that he gives in his paper—there seems no reason why the modulus should not be selected so as to render as rapid as possible the approximations. If we calculate E directly from the equation $\mathrm{M} = \mathrm{E} - e\sin\mathrm{E}$ we have the case corresponding to $k = 0$: here there is only one term to be calculated at each approximation, but it is large, viz. of the order e. When, instead, we replace E and sin E by series, we have more terms to calculate at each approximation, but then we can so determine k that the largest term may be of the order e^2. If the value of k so obtained (that is from the equation $4q = e$) gave so large a value of q that very many terms had to be included, it would be necessary to consider whether it would not be desirable to give some smaller value to q, even though the magnitude of the largest coefficient would thus be increased. It will be found, however, that for all the values of e for which the method is suitable, the value of q is sufficiently small to render the convergence of the terms rapid, so that the assumption $4q = e$ need not be modified on this account.

§ 6. As the equation $4q = e$ is only obtained as an approximation to the equation $\mathrm{A}_1 e = \mathrm{B}_1$, it is clear that there is no advantage in its being *exactly* satisfied, and it will generally be amply sufficient if the modular angle be taken equal to the exact number of degrees nearest to the angle for which $4q = e$.

The following Table gives the values of the coefficients

$$\mathrm{A}_1 = \frac{\pi^2}{k^2\mathrm{K}^2}\frac{4q}{1+q^2}, \quad \mathrm{B}_1 = \frac{4q}{1+q^2},$$

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and also the values of q and $\log q$ for every degree of the modular angle. The values for angles at all near 90° would not, of course, be used, but it seems desirable to give the Table in its integrity.

Table I.

Arc sin k	A_1	B_1	q	$\log q$
°				
1	1·0000000	0·0000762	0·00001904	5·27965680
2	1·0000000	0·0003047	0·00007617	5·88178296
3	0·9999998	0·0006857	0·00017143	6·23407579
4	0·9999995	0·0012195	0·00030487	6·48410778
5	0·9999989	0·0019063	0·00047657	6·67812662
6	0·9999976	0·0027466	0·00068665	6·83673234
7	0·9999954	0·0037409	0·00093522	6·97091369
8	0·9999924	0·0048898	0·00122245	7·08723006
9	0·9999882	0·0061940	0·00154850	7·18991248
10	0·9999817	0·0076543	0·00191359	7·28184993
11	0·9999730	0·0092717	0·00231795	7·36516313
12	0·9999619	0·0110472	0·00276181	7·44119369
13	0·9999476	0·0129817	0·00324547	7·51127726
14	0·9999289	0·0150767	0·00376923	7·57625221
15	0·9999059	0·0173334	0·00433342	7·63683083
16	0·9998783	0·0197532	0·00493841	7·69358743
17	0·9998441	0·0223377	0·00558460	7·74699184
18	0·9998034	0·0250886	0·00627239	7·79743338
19	0·9997550	0·0280077	0·00700226	7·84523825
20	0·9996982	0·0310968	0·00777468	7·89068255
21	0·9996311	0·0343582	0·00859018	7·93400202
22	0·9995537	0·0377938	0·00944930	7·97539964
23	0·9994644	0·0414061	0·01035265	8·01505137
24	0·9993617	0·0451976	0·01130084	8·05311085
25	0·9992446	0·0491708	0·01229456	8·08971301
26	0·9991115	0·0533285	0·01333451	8·12497701
27	0·9989607	0·0576738	0·01442144	8·15900867
28	0·9987908	0·0622096	0·01555616	8·19190236
29	0·9986000	0·0669393	0·01673951	8·22374268
30	0·9983865	0·0718663	0·01797239	8·25460576
31	0·9981482	0·0769944	0·01925575	8·28456038
32	0·9978827	0·0823275	0·02059060	8·31366893
33	0·9975884	0·0878696	0·02197800	8·34198819
34	0·9972621	0·0936250	0·02341909	8·36957004
35	0·9969019	0·0995984	0·02491506	8·39646198

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Arc sin k	A_1	B_1	q	log q
36°	0·9965046	0·1057946	0·02646718	8·42270772
37	0·9960677	0·1122187	0·02807680	8·44834754
38	0·9955875	0·1188761	0·02974532	8·47341870
39	0·9950616	0·1257725	0·03147428	8·49795576
40	0·9944852	0·1329139	0·03326526	8·52199088
41	0·9938557	0·1403068	0·03511996	8·54555404
42	0·9931682	0·1479578	0·03704020	8·56867332
43	0·9924188	0·1558741	0·03902789	8·59137506
44	0·9916026	0·1640633	0·04108507	8·61368404
45	0·9907150	0·1725335	0·04321392	8·63562365
46	0·9897501	0·1812931	0·04541675	8·65721604
47	0·9887027	0·1903511	0·04769603	8·67848227
48	0·9875664	0·1997172	0·05005441	8·69944237
49	0·9863346	0·2094017	0·05249471	8·72011550
50	0·9850005	0·2194155	0·05501993	8·74052006
51	0·9835562	0·2297702	0·05763334	8·76067376
52	0·9819934	0·2404780	0·06033839	8·78059371
53	0·9803034	0·2515525	0·06313883	8·80029653
54	0.9784766	0·2630077	0·06603869	8·81979842
55	0·9765026	0·2748590	0·06904230	8·83911525
56	0·9743697	0·2871227	0·07215437	8·85826262
57	0·9720666	0·2998163	0·07537997	8·87725598
58	0·9695790	0·3129590	0·07872464	8·89611069
59	0·9668930	0·3265712	0·08219438	8·91484211
60	0·9639930	0·3406752	0·08579573	8·93346569
61	0·9608609	0·3552952	0·08953588	8·95199709
62	0·9574782	0·3704574	0·09342267	8·97045226
63	0·9538241	0·3861905	0·09746475	8·98884758
64	0·9498751	0·4025257	0·10167168	9·00719999
65	0·9456061	0·4194977	0·10605402	9·02552714
66	0·9409892	0·4371446	0·11062354	9·04384755
67	0·9359923	0·4555081	0·11539337	9·06218085
68	0·9305806	0·4746350	0·12037825	9·08054801
69	0·9247144	0·4945775	0·12559479	9·09897161
70	0·9183501	0·5153942	0·13106182	9·11747621
71	0·9114365	0·5371509	0·13680085	9·13608879
72	0·9039167	0·5599223	0·14283652	9·15483926
73	0·8957248	0·5837942	0·14919737	9·17376116
74	0·8867853	0·6088652	0·15591666	9·19289252
75	0·8770097	0·6352492	0·16303353	9·21227694

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Arc sin k	A_1	B_1	q	$\log q$
76°	0·8662938	0·6630809	0·17059454	9·23196512
77	0·8545150	0·6925190	0·17865566	9·25201679
78	0·8415247	0·7237544	0·18728518	9·27250342
79	0·8271432	0·7570202	0·19656766	9·29351207
80	0·8111467	0·7926045	0·20660976	9·31515082
81	0·7932526	0·8308727	0·21754895	9·33755699
82	0·7730953	0·8722976	0·22956716	9·36090976
83	0·7501866	0·9175126	0·24291297	9·38545071
84	0·7238497	0·9673968	0·25794020	9·41151903
85	0·6930978	1·0232358	0·27517980	9·43961656
86	0·6563906	1·087040	0·29548839	9·47054042
87	0·6110736	1·162285	0·32040034	9·50569296
88	0·5517805	1·256006	0·35316565	9·54797845
89	0·4637601	1·387542	0·40330931	9·60563824

By means of this Table we can always, for any given value of e (supposed less than $\frac{1}{2}$) at once select that value of the modular angle for which the value of $A_1 e - B_1$ is the least. In the formation of this Table, eight-decimal values of $\log q$ and $\log K$ were used, and $\log A_1$ and $\log B_1$ are given to eight places (except above 85°) in Table II., at the end of the paper. The values of A_1 and B_1 were deduced from those of $\log A_1$ and $\log B_1$ in Table II. by means of ordinary seven-figure logarithms, so that the last figures are not to be relied upon; this applies of course especially to the numbers in the A_1 column, which, commencing generally with nines, were taken out from near the end of the table of logarithms. The values of q, however, were obtained by ten-figure logarithms, and should be correct to the last figure.

§ 7. I take as an example the case of $e = \frac{1}{4}$, $M = 50°$, which is the first of the two examples which Dr. Gyldén has given in his paper. We see at once from the foregoing Table that B_1 is most nearly equal to $\frac{1}{4}A_1$ when $k = \sin 52°$; and taking this value of the modulus and working with seven-figure logarithms, I find

$A_1 = 0·9819934$ $\quad$ $B_1 = 0·2404780$

$A_2 = 0·1189336$ $\quad$ $B_2 = 0·0072813$

$A_3 = 0·0107645$ $\quad$ $B_3 = 0·0002929$

$A_4 = 0·0008660$ $\quad$ $B_4 = 0·0000133$

$A_5 = 0·0000653$ $\quad$ $B_5 = 0·0000006$

$A_6 = 0·0000047$

$A_7 = 0·0000003$

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whence, e being $= \frac{1}{4}$,

$$\begin{aligned} 2\eta = M &+ 0{\cdot}0050203 \sin 2\eta \\ &+ 0{\cdot}0224521 \sin 4\eta \\ &+ 0{\cdot}0023982 \sin 6\eta \\ &+ 0{\cdot}0002032 \sin 8\eta \\ &+ 0{\cdot}0000157 \sin 10\eta \\ &+ 0{\cdot}0000012 \sin 12\eta \\ &+ 0{\cdot}0000001 \sin 14\eta \\ &+ \&c. \end{aligned}$$

and the formulæ are

$$\begin{aligned} 2\eta = M &+ [3{\cdot}01515] \sin 2\eta \\ &+ [3{\cdot}665682] \sin 4\eta \\ &+ [2{\cdot}6943] \sin 6\eta \\ &+ [1{\cdot}6223] \sin 8\eta \\ &+ [0{\cdot}510] \sin 10\eta \\ &+ [9{\cdot}394] \sin 12\eta \\ &+ [8{\cdot}31] \sin 14\eta \\ &+ \&c. \end{aligned} \qquad \begin{aligned} E = 2\eta &+ [4{\cdot}6955006] \sin 2\eta \\ &+ [3{\cdot}176637] \sin 4\eta \\ &+ [1{\cdot}7811] \sin 6\eta \\ &+ [0{\cdot}437] \sin 8\eta \\ &+ [9{\cdot}120] \sin 10\eta \\ &+ \&c. \end{aligned}$$

. . . (11)

where the numbers in [ ] denote the Briggian logarithms of the coefficients expressed in seconds of arc.

When M is put $= 50°$ the successive approximations to 2η are found to be

°	′	″
50		
51	33	4
51	31	51·4
51	31	52·4
51	31	52·4

whence, from the formula for 2 am v, $= E$, it results that

$$E = 62° \ 43' \ 55''{\cdot}9.$$

§8. In Dr. Gyldén's paper the process is as follows :—

$$e = \frac{1}{4}, \text{ whence } k^2 = \frac{2}{5}, \quad k'^2 = \frac{3}{5},$$

and using the formula $q = \lambda + 2\lambda^5 + \&c.$
where

$$\lambda = \frac{1}{2} \frac{k^2}{(1+k')(1+\sqrt{k'})^2},$$

it is shown that

$$\log q = 8{\cdot}503565 ;$$

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whence, from the formula

$$\frac{2K}{\pi} = (1 + 2q + 2q^4 + 2q^9 + \&c.)^2$$

$$\log \frac{2K}{\pi} = 0{\cdot}053694.$$

It is thus found that

$$\begin{aligned} 2\eta = M &+ [4{\cdot}398392] \sin 2\eta \\ &+ [3{\cdot}455685] \sin 4\eta \\ &+ [2{\cdot}16940] \sin 6\eta \\ &+ [0{\cdot}799] \sin 8\eta \\ &+ [9{\cdot}415] \sin 10\eta \\ &+ \&c. \end{aligned} \qquad \begin{aligned} 2\operatorname{am} v = 2\eta &+ [4{\cdot}419607] \sin 2\eta \\ &+ [2{\cdot}62258] \sin 4\eta \\ &+ [0{\cdot}950] \sin 6\eta \\ &+ [9{\cdot}319] \sin 8\eta \\ &+ \&c. \end{aligned} \quad \ldots \quad (12)$$

Dr. Gyldén starts with $2\eta = 56°$ as a first approximation, and finds the successive approximations to be

°	′	″
56	32	4
56	32	6·2

giving

$$E_1 = 2\operatorname{am} v_1 = 62° 43' 56''{\cdot}0.$$

But in order to compare the approximations by means of (12) with that obtained from (11), it is necessary to commence the approximation with $2\eta = 50°$. The approximations thus obtained are shown below in the second column; and for the sake of comparison those derived by the direct determination of E from the equation

$$E = M + \frac{1}{4} \sin E,$$

that is from

$$E = M + [4{\cdot}7123651] \sin E \quad \ldots \ldots \quad (13)$$

are added in the third column.

$$e = \frac{1}{4}, \quad M = 50°.$$

Approximations obtained from (11).			Approximations obtained from (12).			Approximations obtained from (13).		
°	′	″	°	′	″	°	′	″
50			50			50		
51	33	4	56	7	35	60	58	22
51	31	51·4	56	30	46	62	31	29
51	31	52·4	56	32	2	62	42	30
51	31	52·4	56	32	6·1	62	43	46
giving			56	32	6·3	62	43	54·8
$E = 62$	43	55·9	56	32	6·3	62	43	55·8
			giving			62	43	55·9
			$E = 62$	43	56·0	62	43	55·9

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Thus, not counting the first approximation, viz. 50°, we obtain the final value from (11) in three approximations, from (12) in five, and from (13) in seven. The difference of a tenth of a second in the values of E is unimportant, as a last-figure error of a unit is of course quite possible. It was not necessary to calculate the earlier approximations to seconds, but it was convenient for the sake of uniformity to carry all the approximations to this extent.

§ 9. Dr. Gyldén's value of k is $\sqrt{\left(\frac{2}{5}\right)}$ corresponding to a modular angle of 39° 14′, while the modular angle in (11) was 52°. The corresponding values of q are 0·0318834 and 0·0603384: but only one more term is required in (11) than in (12).

On calculating the coefficient of sin 2η with Dr. Gyldén's value of q, I find it to be

$$0{\cdot}994935\, e - 0{\cdot}127404$$

which, putting $e = \frac{1}{4}$, becomes

$$0{\cdot}248734 - 0{\cdot}127404$$

so that in this case the subtraction of the second series only diminishes the coefficient of sin 2η in the first by about one-half: and the whole coefficient is equal to about one-half of e.

Expressed in seconds the values of the coefficients of the terms in (11) and (12) are

	In (11).	In (12).
	"	"
Sin 2η	1035·5	25026·0
Sin 4η	4631·1	2855·5
Sin 6η	494·7	147·7
Sin 8η	41·9	6·3
Sin 10η	3·2	0·3
Sin 12η	0·2	

and the sum of all the coefficients in (11) is 6207″ or 1° 43′ 27″, and in (12) 28036″ or 7° 47′ 16″. The coefficient in (13) is 51566″ or 14° 19′ 26″.

Another advantage that results from obtaining the modular angle from the Table in § 6, instead of determining it as an analytical function of e, is that in the former case all the necessary tables can be calculated beforehand. It was this, in fact, which, when reading Dr. Gyldén's paper, first led me to examine the subject, as the existence of an exact analytical relation between q and e required that the computer should himself calculate, for each given value of e, the values of K and q; and this would be avoided if use could be made, instead, of a small table of these quantities. In the practical application of the method, it certainly would be an important gain, both in

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point of labour and accuracy, to have the K's and q's given, as the necessity for the calculation of them by the user of the method seemed of itself to form a serious objection to its employment, except in those cases where so many values of E were required that the preliminary calculations might be relatively disregarded.

§ 10. By means of the equation $q = \frac{1}{4} e$ we can of course express k in terms of e, though the general term cannot be exhibited, as there is no q-series for k. Starting, however, with the series for $\log k$, viz. :

$$\log k = \log 4\sqrt{q} - \frac{4q}{1+q} + \frac{4q^2}{2(1+q^2)} - \frac{4q^3}{3(1+q^3)} + \&c.$$

$$= \log 4\sqrt{q} - 4q + 6q^2 - \frac{16}{3} q^3 + 3q^4 - \&c.,$$

we have

$$k = 4\sqrt{q}.e^{-4q+6q^2-\&c.}$$

$$= 4\sqrt{q}\{1 - 4q + 14q^2 - 40q^3 + 101q^4 - \&c.\}$$

$$= 2\sqrt{e}\{1 - e + \frac{7}{8} e^2 - \frac{5}{8} e^3 + \frac{101}{256} e^4 - \&c.\},$$

Dr. Gyldén's value being

$$k = \sqrt{\left(\frac{2e}{1+e}\right)}$$

$$= \sqrt{(2e)}\{1 - \frac{1}{2} e + \frac{3}{8} e^2 - \frac{5}{16} e^3 + \&c.\}.$$

Thus the former series gives the greater value of q; but the following table shows better the amount of difference between the formulæ:

	(α) $q = \frac{1}{4} e$	(β) $k = \sqrt{\left(\frac{2e}{1+e}\right)}$			
e	k from (α)	k from (β)	e	k from (α)	k from (β)
	°	° ′		°	° ′
$\frac{1}{20}$	25	17 59	$\frac{5}{20}$	52	39 14
$\frac{2}{20}$	35	25 14	$\frac{6}{20}$	56	42 48
$\frac{3}{20}$	42	30 43	$\frac{7}{20}$	60	46 4
$\frac{4}{20}$	48	35 16	$\frac{8}{20}$	63	49 6

§ 11. Dr. Gyldén seems, as stated in § 5, to have been led to the value of the modulus which he adopted by analytical considerations, which have reference to the treatment of the general question of elliptic motion; while in this paper the object has

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been to reduce, as far as possible, the numerical calculations required for the solution of Kepler's problem. I have confined myself entirely to the solution of Kepler's problem—that is, to the determination of E from the equation $E = M + e \sin E$ by means of elliptic functions—and though it is true that Dr. Gyldén does so too in the examples in his paper, he does not appear to have specially considered the solution of this question apart from the more general investigation. If the true anomaly f be required in terms of M, probably the best method would in every case be to obtain E from M and then to deduce f from E by the trigonometrical formula (1).

The q-formula for tan am v is

$$\frac{\pi}{2kK}\{\tan\eta - \frac{4q^2}{1+q^2}\sin 2\eta + \frac{4q^4}{1+q^4}\sin 4\eta - \&c.\},$$

and it is clear that since the q-coefficients are different from those in the series for am v or sn v cn v, it would be most convenient to first calculate E, $= 2$ am v, and then have recourse to (1) to obtain f. Also the form into which (1) is transformed, viz. coam $u = 90° - \text{am}\, v$, that is, am $(K-u) = 90° - \text{am}\, v$, or, as we may write it,

$$K - u = F(90° - \tfrac{1}{2}E, k),$$

is not preferable to (1) for the calculation of u or f; so that, as far as the numerical solution of Kepler's problem is concerned, the value of k given by (3) does not present any special advantages.

§ 12. The other example which Dr. Gyldén takes is $e = \frac{1}{2}$, $M = 60°$. It is not a very satisfactory one for the method in any case, as e is rather too large; and it is even less favourable as an example of the process of solution suggested in this paper, for in the reasoning in §§ 4 and 5 e^2 has been supposed to be considerably less than e, and this is not the case if e be as large as $\frac{1}{2}$.

In this case the Table in § 6 shows that $A_1 e - B_1$ is smallest when $k = \sin 68°$, and the formulæ are

$2\eta = M -$	[3·28499]	$\sin 2\eta$	$2\,\text{am}\, v = 2\eta +$	[4·9907850]	$\sin 2\eta$
$+$	[4·242028]	$\sin 4\eta$	$+$	[3·77646]	$\sin 4\eta$
$+$	[3·57437]	$\sin 6\eta$	$+$	[2·68101]	$\sin 6\eta$
$+$	[2·8035]	$\sin 8\eta$	$+$	[1·6366]	$\sin 8\eta$
$+$	[1·9915]	$\sin 10\eta$	$+$	[0·620]	$\sin 10\eta$
$+$	[1·1568]	$\sin 12\eta$	$+$	[9·622]	$\sin 12\eta$
$+$	[0·308]	$\sin 14\eta$	$+$	[8·64]	$\sin 14\eta$
$+$	[9·455]	$\sin 16\eta$	$+$	&c.	
$+$	[8·59]	$\sin 18\eta$			
$+$	&c.				

. . . (14)

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Dr. Gyldén has

$$k = \sqrt{\left(\frac{2}{3}\right)} = \sin 54^\circ 44',$$

and his formulæ are

$$\begin{aligned} 2\eta = M &+ [4{\cdot}650549] \sin 2\eta \\ &+ [4{\cdot}075356] \sin 4\eta \\ &+ [3{\cdot}12280] \sin 6\eta \\ &+ [2{\cdot}0940] \sin 8\eta \\ &+ [1{\cdot}029] \sin 10\eta \\ &+ [9{\cdot}945] \sin 12\eta \\ &+ [8{\cdot}86] \sin 14\eta \\ &+ \&c. \end{aligned} \qquad \begin{aligned} 2\,\mathrm{am}\,v = 2\eta &+ [4{\cdot}748494] \sin 2\eta \\ &+ [3{\cdot}283498] \sin 4\eta \\ &+ [1{\cdot}9415] \sin 6\eta \\ &+ [0{\cdot}651] \sin 8\eta \\ &+ [9{\cdot}387] \sin 10\eta \\ &+ \&c. \end{aligned} \quad \ldots \quad (15)$$

while the original equation $E = M + e \sin E$ becomes

$$E = M + [5{\cdot}0133951] \sin E \quad \ldots \quad (16)$$

The approximations derived from these three formulæ are shown below:—

$$e = \frac{1}{2}, \quad M = 60^\circ.$$

From (14).	From (15).	From (16).
° ′ ″	° ′ ″	° ′ ″
60	60	60
63 34	73 36	84 49
63 0 26	73 26 15	88 32
63 5 48·6	73 26 39·4	88 38 19
63 4 57·2	73 26 38·3	88 38 23·3
63 5 5·5	73 26 38·4	88 38 23·3
63 5 4·1	73 26 38·4*	
63 5 4·3	giving	
63 5 4·3	E = 88 38 23·2	
giving		
E = 88 38 23·4		

Thus, using (14) there are seven approximations, using (15) five, and using (16) only four. The reason of this is that the greatest term in (15) is the first, viz. that which involves $\sin 2\eta$, and as 2η in this example is equal to about 73°, a small change in the angle produces but a slight alteration in the sine, and the approximation is rapid. It is even more so in (16), where the

* I have recalculated and slightly altered Dr. Gyldén's last approximations, so that all three sets should be exactly similar to one another. Dr. Gyldén's last two approximations are 73° 26′ 39″·4 and 73° 26′ 38″·2, giving E = 88° 38′ 23″·0.

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angle is very nearly equal to 90°. But in (14) the greatest term is that which involves $\sin 4\eta$, and 4η is equal to about 126°, which is not far distant from the middle of the quadrant, so that a change in 2η produces a considerable alteration in the value of $\sin 4\eta$. All this will be reversed when 4η in (14) is nearer to 90° than 2η in (16). Take for example $M = 30°$ and the approximations are as follows:—

$$e = \frac{1}{2}, \quad M = 30°.$$

From (14).	From (15).	From (16).
° ′ ″	° ′ ″	° ′ ″
30	30	30
35 8	39 28	44 19
35 22 25	41 28 32	50 1
35 22 44·0	41 49 5	51 57 3
35 22 44·3	41 52 24·6	52 33 35
35 22 44·3	41 52 56·6	52 44 46
giving	41 53 1·8	52 48 9
E = 52 49 37·6	41 53 2·6	52 49 11
	41 53 2·8	52 49 29
	41 53 2·8	52 49 34·9
	giving	52 49 36·7
	E = 52 49 37·6	52 49 37·2
		52 49 37·4
		52 49 37·5
		52 49 37·5

Here 4η in (14) is equal to about 71°, and 2η in (15) to about 42°; and as E is only about 53° the approximation by (16) is not very rapid—in fact, by (14) there are four approximations, by (15) eight, and by (16) thirteen.

In this case of $e = \frac{1}{2}$ there is not much to choose between the two formulæ, as the reasoning in § 4 is not appropriate when e is so large: for the object was to cause the term of the first order in e to nearly disappear, the next term (in which the coefficient was approximately $= \frac{3}{8}e^2$) being the largest; but as this term involves $\sin 4\eta$, a small change in the value of 2η produces double the effect that it would if $\sin 2\eta$ were involved instead; so that when $e = \frac{1}{2}$ the advantage arising from the term being of the second order is nearly neutralised. This is pretty evident; but it may be seen perhaps more clearly by expanding x by Lagrange's theorem (i) when $x = M + e \sin x$ and (ii) when $x = M + e \sin 2x$.

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The values of the coefficients of the terms in (14) and (15) are

	In (14).	In (15).
	"	"
sin 2η	1927·5	44724·9
sin 4η	17459·3	11894·8
sin 6η	3752·9	1326·8
sin 8η	636·1	124·2
sin 10η	98·1	10·7
sin 12η	14·3	0·9
sin 14η	2·0	0·1
sin 16η	0·3	

and the sum of all the coefficients in (14) is 23890″ or 6° 38′ 10″, and in (15) is 58082″ or 16° 8′ 2″. Only one more term is required in (14) than in (15), as the term in sin 18η can never be sensible. The coefficient in (16) is equal to 103132″ or 28° 38′ 52″.

§ 13. In regard to the practical use of the method Dr. Gyldén remarks, and very truly, that the calculations are much less laborious than at first sight they appear to be, as only approximate values of the arguments are required in the smaller terms. Also when 2η is found the value of 2 am v is obtained with great ease, as the values of log sin 2η, log sin 4η, &c., have been already calculated. The obvious objection to the method is the great number of logarithmic entries that are required: and this objection seems so serious as almost to be fatal to its adoption. As far as the three examples given in this paper are concerned, the old trigonometrical method is certainly preferable; but this might not be the case perhaps if the value of E were smaller, say not exceeding 30° or 40°, when the number of approximations would be considerable. I must admit that while working out the examples in §§ 7, 8, and 12, the conclusion rather forced itself upon me that the method was too complicated and elaborate for ordinary practical use, and that some of the numerous other methods that have been given for the solution of Kepler's problem must be superior to it. I have, however, made no other numerical comparisons besides those described in this paper; and Dr. Gyldén's words seem to imply that he has found the mode of solution proposed by him to be convenient and useful. If a more complete examination should render it probable that the elliptic function method might be of practical value, I would calculate the necessary tables of the values of the second and succeeding terms. My intention was to have appended them to this paper, and some of the calculations were performed; but, as the above comparisons tended rather to show that the method was not a very good one in practice, they have been laid aside: it seems worth while, however, to give the values of $\log A_1$ and $\log B_1$ for every degree, which are contained in Table II., and the values of the quantities involved in

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the coefficients of the second and third terms, viz., A_2, B_2, A_3, B_3, for every fifth degree, which are contained in Table III.; as these may be found useful in any further discussion of the question. Table III. was obtained by means of seven-figure logarithms, so that the last figures are liable to small errors. Table II. is referred to at the end of §6. I am in great hopes that Dr. Gyldén or some other astronomer who has used the method may be tempted by this paper to make some further remarks in regard to it.

Whether the elliptic function method should be found to be practically important or not, the substitution for E and sin E of two series proceeding by multiples of 2η and whose coefficients depend upon an arbitrary quantity k is a remarkable transformation of the question, and the form assumed by the equation $M = E - e \sin E$, viz.

$$M = 2\left(\mathrm{am}\, v + \frac{e}{k^2}\frac{d^2}{dv^2}\mathrm{am}\, v\right),$$

is noticeable, for, as a consequence of it, the q-coefficients of the two series are identical, to a factor *près*. It certainly seemed desirable to examine the effect of these transformations: and the practical advantages and defects of the method could not well have been exhibited otherwise than by means of numerical examples.

I ought to mention that Dr. Gyldén only gives the method discussed in this paper as appropriate when e does not exceed $\frac{1}{2}$: he proposes a different mode of solution by means of elliptic functions for the case of $e > \frac{1}{2}$, which I have not examined.

Table II.

Arc sin k	log A_1	log B_1
°		
1	9·99999999	5·88171679
2	9·99999999	6·48384295
3	9·99999996	6·83613578
4	9·99999983	7·08616777
5	9·99999950	7·28018652
6	9·99999895	7·43879211
	9·99999809	7·57297329
8	9·99999676	7·68928940
9	9·99999479	7·79197143
10	9·99999202	7·88390832
11	9·99998831	7·96716078
12	9·99998344	8·04325038

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Arc sin k	log A_1	log B_1
13°	9·99997715	8·11333269
14	9·99996913	8·17830603
15	9·99995919	8·23888265
16	9·99994702	8·29563682
17	9·99993226	8·34903828
18	9·99991458	8·39947630
19	9·99989354	8·44727696
20	9·99986877	8·49271631
21	9·99983976	8·53602996
22	9·99980611	8·57742085
23	9·99976726	8·61706480
24	9·99972271	8·65511539
25	9·99967176	8 69170734
26	9·99961392	8·72695978
27	9·99954842	8·76097834
28	9·99947456	8·79385726
29	9·99939161	8·82568099
30	9·99929872	8·85652550
31	9·99919498	8·88645936
32	9·99907951	8·91554481
33	9·99895137	8·94383847
34	9·99880934	8·97139188
35	9·99865242	8·99825244
36	9·99847937	9·02446359
37	9·99828889	9·05006531
38	9·99807953	9·07509459
39	9·99784995	9·09958575
40	9·99759841	9·12357055
41	9·99732333	9·14707871
42	9·99702280	9·17013786
43	9·99669495	9·19277403
44	9·99633768	9·21501156
45	9·99594870	9·23687340
46	9·99552553	9·25838113
47	9·99506569	9·27955541
48	9·99456628	9·30041564
49	9·99402427	9·32098035
50	9·99343640	9·34126734
51	9·99279913	9·36129359

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		log B,
	9·99210856	9·38107544
	9·99136048	9·40062864
	9·99055043	9·41996853
	9·98967336	9·43910996
	9·98872383	9·45806741
	9·98769602	9·47685526
58	9·98658326	9·49548740
59	9·98537851	9·51397791
60	9·98407385	9·53234059
61	9·98266051	9·55058935
62	9·98112889	9·56873825
63	9·97946823	9·58680151
64	9·97766654	9·60479368
65	9·97571033	9·62272967
66	9·97358459	9·64062507
67	9·97127225	9·65849611
68	9·96875396	9·67635984
69	9·96600769	9·69423447
70	9·96300824	9·71213958
71	9·95972642	9·73009630
72	9·95612842	9·74812782
73	9·95217468	9·76625982
74	9·94781856	9·78452110
75	9·94300437	9·80294417
76	9·93766522	9·82156648
77	9·93171963	9·84043165
78	9·92506689	9·85959125
79	9·91758073	9·87910753
80	9·90909936	9·89905660
81	9·89941153	9·91953447
82	9·88823308	9·94066468
83	9·87516937	9·96261199
84	9·85964844	9·98560468
85	9·84079450	0·00997574
86	9·8171624	0·0362456
87	9·7860937	0·0653128
88	9·7417663	0·0989917
89	9·6662934	0·1422460

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Table III.

Arc sin k	A_1	B_1		log B_1
°				
5	0·0009531	0·0000005	0·0000000	8·11333269
10	0·0038271	0·0000073	0·0000110	8·23888265
15	0·0086662	0·0000376	0·0000563	8·563682
20	0·0155456	0·0001209	0·0001813	0·828
25	0·0245743	0·0003023	0·0004532	0·000
30	0·0358984	0·0006460	0·0009678	0·000007
35	0·0497066	0·0012415	0·0018577	0·0000206
40	0·0662368	0·0022132	0·0033051	0·0000491
45	0·0857849	0·0037349	0·0055607	0·0001076
50	0·1087164	0·0060543	0·0089724	0·0002221
55	0·1354796	0·0095335	0·0140311	0·0004388
60	0·1666215	0·0147210	0·0214443	0·0008420
65	0·2028009	0·0224921	0·0322658	0·0015904
70	0·2447840	0·0343443	0·0481367	0·0030017
75	0·2933576	0·0531223	0·0717900	0·0057778
80	0·3488540	0·0852199	0·1083035	0·0117586
85	0·4079986	0·1505844	0·1693016	0·0277715

Trinity College, Cambridge,
1877, March 20.

Some Experiments Bearing on the Transit of Venus.

By the Rev. S. J. Perry.

A short time since I had the honour of bringing before the Royal Astronomical Society the researches of M. Ch. André on the subject of Instrumental Diffraction in its connection with the Transit of *Venus*, and he has since desired me to supplement my paper by one or two historical remarks:—

1. The main facts adduced by M. André were verifications of results previously obtained by Schwerd, whose theory was completed by André.

2. Professor Kaiser had already pointed out the importance of the question of diffraction in the study of telescopic images.

3. M. Van de Sande Backuysen, successor of Professor Kaiser in the direction of the Leyden Observatory, explained the black drop as a phenomenon of diffraction in a Note addressed to the *Astronomische Nachrichten*, May 11, 1874.

I have lately received from M. Alfred Angot two very interesting papers for presentation to the Society. The subject matter of these communications is one to which he has, in con-

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with M. André, devoted much time and labour during
est few years. M. Angot was sent as companion to M.
é, in the French Government Expedition to Noumea, New
edonia, to observe the late Transit of *Venus*, and he has since
en engaged in measuring the French daguerreotypes and pho-
ographs taken on December 8, 1874. I cannot do better than
let him communicate his results in his own words.

Etude sur les Images Photographiques obtenues au foyer des Lunettes Astronomiques. Par M. Alfred Angot.

On sait depuis longtemps que l'image photographique d'un objet lumineux est dilatée aux dépens des parties obscures ou du champ lui-même, et cela d'autant plus que l'objet est plus vivement éclairé. Pendant longtemps, on s'est borné à attribuer cet effet à un *cheminement* de proche en proche de l'action chimique, sans plus l'étudier. Les applications que l'on tente actuellement de faire de la photographie aux mesures de précision, notamment à celles que demande l'astronomie, rendaient nécessaire l'étude approfondie de ce phénomène.

Le travail qui suit a été effectué dans les caves de l'Ecole Normale Supérieure. Grâce à la bienveillance de M. H. Sainte-Claire Deville, j'ai pu mettre à profit toutes les ressources de son laboratoire, et m'installer dans une cave de 90 mètres de longueur en ligne droite, à côté des appareils qui servaient à la même époque à M. André pour son étude de la diffraction dans les instruments d'optique.

I. *Marche des Expériences.*

Les images photographiques ont été obtenues sans grossissement au foyer d'une lunette que la Commission du Passage de Vénus a bien voulu mettre à ma disposition, et qui m'avait servi à l'observation même du passage à Nouméa (Nouvelle-Calédonie). L'objectif, de $0^m{\cdot}13$ d'ouverture, achromatisé par l'écartement des deux lentilles qui le composent, a $3^m{\cdot}80$ de distance focale. Une longueur de $1/500^e$ de millimètre, mesurée sur les épreuves photographiques, correspond ainsi à un angle de $0''{\cdot}109$.

Les épreuves ont été mesurées avec une des machines construites par MM. Brünner pour la Commission du Passage de Vénus, et qui permettent d'évaluer rapidement et avec certitude le $1/500^e$ de millimètre—quantité bien suffisante pour mes recherches.

L'objet photographié, disposé à environ 87 mètres de l'objectif, est une source lumineuse formée de deux rectangles égaux séparés par un intervalle obscur. Ces rectangles sont découpés dans une lame métallique que l'on applique sur une plaque de verre

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dépoli, éclairée par derrière avec une lampe Drummond ou la lumière électrique. On réalise ainsi un éclairement uniforme de l'objet photographié—condition absolument indispensable.

Avec cette disposition on peut obtenir facilement, non-seulement le fait de l'augmentation des images, mais la mesure de cette augmentation en valeur absolue. L'augmentation de dimensions de chaque rectangle lumineux est en effet forcément égale à la diminution de l'intervalle obscur compris entre eux : la somme de ces deux quantités est donc constante et égale à ce qu'elle serait si l'image se formait seulement d'après les lois de l'optique géométrique. On connaît de plus, par la mesure directe de l'objet photographié, le rapport des intervalles obscur et lumineux. Possédant leur somme et leur rapport, on calcule facilement leur valeur pour l'image géométrique ; la comparaison avec celles que donne la mesure directe des épreuves donne dans chaque cas, et en valeur absolue, l'augmentation des dimensions de l'image. En outre, la constance de la somme des intervalles obscur et lumineux donne un excellent moyen d'apprécier le degré de précision des expériences.

Pour permettre de juger cette précision, je citerai seulement ici les résultats suivants des mesures de sept images obtenues successivement sur une même plaque daguerrienne, et pour lesquelles on n'a fait varier que la durée d'exposition à la lumière :

	Largeur (en 1/500es de millimètre)		
Durée de pose	du rectangle lumineux l	de l'intervalle obscur o	Somme $l+o$
10 secondes	593·5	192·6	786·1
30 „	618·5	168·6	787·1
40 „	624·0	163·6	787·6
1 minute	632·6	155·2	787·8
2 minutes	645·7	141·4	787·1
4 „	656·4	130·0	786·4
7 „	673·8	113·4	787·2

On voit que l'erreur moyenne sur la somme, qui devrait être constante, ne dépasse pas $0^{mm}\cdot001$ ($0''\cdot05$). Dans ce qui suit, nous nous bornerons à indiquer l'excès de l'image sur l'image géométrique calculée, comme nous l'avons indiqué plus haut, au moyen de la somme $l+o$, et du rapport $\frac{L}{O}$ mesuré directement sur l'objet photographié.

II. *Résultats.*

Les expériences ont montré que la dimension des images varie, 1° avec l'intensité de la lumière ; 2° avec la durée de pose ; 3° avec la sensibilité de la plaque ; 4° avec le diamètre de l'objectif ;

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5° avec l'état chimique de la plaque; les phénomènes étant différents si la plaque a vu ou non le jour avant de recevoir l'impression photographique.

1°. *Influence de l'intensité.*—Toutes choses restant égales, l'image augmente à mesure que l'on fait croître l'intensité de la lumière; l'image obtenue est généralement plus grande que l'image géométrique [en supposant un objet lumineux sur fond obscur]. Mais, pour une intensité assez faible, on peut obtenir une image *plus petite* que l'image géométrique. Le phénomène change de sens si l'on considère l'image d'un objet obscur sur champ lumineux.

Je citerai seulement comme exemple l'expérience suivante, qui donne l'excès de l'image obtenue sur l'image géométrique calculée pour des intensités variant de 1 à 38 :

Plaque daguerrienne (durée de pose, 1 minute).

Intensité de la source lumineux	Excès de l'image sur l'image géométrique	
	en 1/500mes de millimètre	en secondes d'arc
		"
1	116·1	12·66
1/4	81·0	8·84
1/9	41·5	4·52
1/9·5	39·2	4·27
1/38	−22·4	−2·44

Le signe − devant le dernier nombre indique que l'image obtenue est plus petite que l'image géométrique.

2°. *Influence de la durée de pose.*—La durée de pose a une influence de même ordre que l'intensité; l'image obtenue croît avec elle. J'ai cité plus haut un exemple de cette influence. Le résultat général est qu'il n'y a pas proportionnalité entre la durée de pose et l'intensité, les effets de la durée de pose étant beaucoup moins grands que ceux de cette dernière. Un temps de pose 1 avec une intensité 2 produisent, par exemple, un effet plus grand qu'un temps de pose 2 avec une intensité 1.

3°. *Influence de la sensibilité de la plaque.*—Pour une même durée de pose et une même intensité lumineux les phénomènes s'accroissent avec la sensibilité de la plaque sans qu'il soit cependant possible de donner une loi numérique, la sensibilité n'étant pas définie rigoureusement. Mes expériences permettent, au contraire, de déterminer la sensibilité en la mesurant, par exemple, par l'inverse de l'intensité lumineuse, qui donnera, avec une durée de pose de 1 seconde, une image égale à l'image géométrique.

4°. *Influence du diamètre de l'objectif.*—Pour vérifier la loi de l'ouverture de l'objectif, j'ai réduit celui-ci à moitié, mais en quadruplant alors l'intensité de la lumière, de façon que l'éclat de l'image fût constant, la durée de pose étant alors la même dans les deux cas.

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Je citerai seulement les nombres suivants :

		Excès de l'image obtenue sur l'image géométrique en 1/500es de millimètre
Première expérience	ouverture 1	27·0
	„ 1/2	43·0
Deuxième expérience	ouverture 1	50·2
	„ 1/2	72·0

L'image augmente donc quand l'ouverture de l'objectif diminue.

5°. *Influence de l'exposition antérieure à la lumière.*—J'ai exposé à la lumière diffuse une moitié de chaque plaque, et j'ai fait ensuite sur les deux moitiés une série d'épreuves avec la même durée de pose et la même intensité, de façon que toutes les conditions fussent identiques de part et d'autre, sauf l'exposition antérieure à la lumière. L'expérience a montré constamment que l'image obtenue sur la moitié intacte était plus grande que sur celle qui avait préalablement été impressionnée par la lumière diffuse. Je citerai seulement les nombres suivants :

			Largeur de l'image	
		Durée de pose	dans la partie exposée antérieurement à la lumière	dans la partie non exposée
1° plaque daguerrienne		30 secondes	514·9	535·6
		1 minute	537·3	560·4
		4 minutes	563·0	581·5
2° plaque, sur collodion sec	intensité 1	1 minute	584·5	622·7
		2 minutes	620·5	641·0
	intensité environ 1/4	1 minute	516·5	558·0
		2 minutes	558·5	579·0

III. *Théorie.*

La première hypothèse que l'on ait invoquée pour expliquer ces faits était d'admettre un *cheminement* de proche en proche de l'action chimique. Mais il est facile de voir que telle ne saurait être la cause de l'agrandissement observé généralement. Tout d'abord, cette hypothèse ne saurait rendre compte de ce fait, qu'avec une faible intensité ou une courte durée de pose on obtient des images plus petites que l'image géométrique. De plus, s'il y avait un cheminement, il devrait être plus grand sur une plaque ayant déjà subi l'action de la lumière diffuse que sur une autre non altérée, et nous avons vu que l'expérience donnait un résultat précisément contraire. Enfin, en augmentant la durée de pose on devrait accroître le cheminement, en lui donnant plus de temps pour se produire, et une durée de pose 2 avec une intensité 1 donnerait une image plus grande qu'une durée de pose 1 avec

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une intensité 2—fait contredit par l'expérience. Il faut donc abandonner cette hypothèse.

La théorie des phénomènes lumineux donne, au contraire, une explication fort simple de tous les phénomènes observés, en admettant seulement, ce qui semble du reste évident, qu'une plaque de sensibilité donnée ne peut être impressionnée pendant le même temps que par des lumières possédant une intensité supérieure à une intensité donnée : cette intensité qui définira justement la sensibilité de la plaque, si l'on peut mesurer en valeur absolue l'intensité limite qui donne une impression pendant l'unité de temps. L'étude de la diffraction au foyer des lentilles faite par Schwerd (*Beugungserscheinungen*), simplifiée et étendue par M. André ('Etude de la Diffraction dans les Instruments d'Optique'—*Annales de l'Ecole Normale Supérieure*, 1876, tome v. page 275), conduit aux résultats suivants. L'intensité lumineuse n'est pas constante en dedans même de l'image géométrique: elle décroît près des bords, et, au bord même, elle n'est que la moitié de ce qu'elle est au centre. En dehors de l'image géométrique on trouve encore de la lumière dont l'intensité décroît progressivement en tendant vers zéro. Si l'on considère un objectif parfait, rigoureusement aplanétique, la largeur de cette zone de diffraction varie en raison inverse de l'ouverture de l'objectif.

L'aberration produit des phénomènes analogues qui se superposent aux précédents et augmentent considérablement l'étendue de la zone diffractée, sans cependant changer le sens général du phénomène. Quand on réduit l'objectif on a toutefois à tenir compte de deux effets inverses ; celui de la diffraction qui augmente, et celui de l'aberration qui diminue en même temps que décroît l'ouverture de l'objectif.

Ces lois suffisent à expliquer tous les faits observés. Quand on augmente l'intensité de la source, l'intensité croît proportionnellement en chacun des points de la zone diffractée, et la plaque photographique, qui reste sensible pour une intensité absolue déterminée, donne des images de plus en plus grandes. Si, au contraire, l'intensité décroît assez pour que, dans le temps considéré, la plaque ne soit plus sensible à la moitié de l'intensité au centre de la plaque, on aura des images plus petites que l'image géométrique.

Au lieu de faire varier l'intensité, on peut faire intervenir la durée de pose ; on aura alors des effets analogues à ceux que donnait la variation de l'intensité, mais moins rapides. En augmentant l'exposition, on rend en effet la plaque sensible à des lumières de plus en plus faibles ; mais cette sensibilité tend rapidement vers une certaine limite, car l'expérience semble prouver que toute intensité qui tombe au-dessous d'une certaine limite, variable avec la sensibilité de la plaque, ne peut plus produire d'impression même pendant un temps infiniment grand.

L'influence de l'ouverture de l'objectif est également manifeste : la zone diffractée augmente quand l'ouverture de l'objectif diminue, et exactement en raison inverse de celle-ci. L'expérience

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a montré cette augmentation, mais un peu moins rapide que ne le veut la théorie ; en effet, en même temps que la diminution de l'ouverture produit une augmentation de la zone diffractée, elle diminue notablement l'effet de l'aberration.

Enfin, quand on soumet à la lumière diffuse la plaque sensible avant d'y imprimer l'image, celle-ci vient se faire sur un champ déjà éclairé, et cet éclairement général masque une partie de l'agrandissement diffractionnel.

En résumé, les faits observés sont en parfait accord avec la théorie. La dimension des images photographiques varie avec toutes les conditions de l'expérience ; mais, pour expliquer ces variations, il suffit d'avoir recours aux théories ordinaires de l'optique, et non à l'hypothèse d'un cheminement mystérieux des actions chimiques. Dans une prochaine communication, j'exposerai les applications de ces recherches à l'observation photographique de certains phénomènes astronomiques, notamment à celle du passage de Vénus.

Sur l'Application de la Photographie à l'Observation du Passage de Vénus. *Par* M. Alfred Angot.

Dans un précédent travail, j'ai étudié les causes diverses qui peuvent modifier la dimension des images photographiques, et montré que tous les faits observés sont d'accord avec la théorie de la diffraction. Je désire exposer aujourd'hui les résultats auxquels conduisent mes expériences pour l'application de la photographie à l'observation du passage de *Vénus*.

Avec la méthode d'observation photographique, on peut chercher à déterminer par deux procédés différents la parallaxe solaire au moyen du passage de *Vénus*. 1°. On cherche à mesurer l'effet parallactique direct, c'est-à-dire la différence des positions apparentes de *Vénus* vue au même instant de deux stations éloignées. 2°. On détermine seulement par la photographie l'instant des contacts. Ce dernier procédé conduit identiquement aux mêmes calculs que l'observation directe, qu'il ne fait que doubler. Le premier, au contraire, est propre à la photographie, puisque les astronomes n'ont pas encore imaginé de moyens sûrs de mesurer les distances de *Vénus* et du Soleil à un instant quelconque.

I. *Mesure directe de l'Effet Parallactique.*

La position de *Vénus* sur le Soleil est définie par deux éléments : la distance des centres et l'angle que fait la ligne des centres avec une direction fixe, celle de l'équateur, par exemple, angle que l'on désigne communément sous le nom *d'angle de*

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position. Mais, pour déterminer la valeur de la parallaxe, il suffit de connaître les valeurs d'une seule de ces deux quantités mesurées au même moment en deux stations convenablement choisies. De là deux manières de mesurer directement l'effet parallactique :—1°, par l'angle de position ; 2°, par la distance des centres. Nous allons examiner successivement ces deux procédés.

1°. *Mesure de l'angle de position.*—D'après les phénomènes que nous avons décrits dans la première partie de ce travail, il est évident que les diamètres photographiques du Soleil et de *Vénus* seront variables avec toutes les conditions de l'expérience, intensité de la lumière, transparence de l'atmosphère, durée de pose, sensibilité de la plaque, etc. Mais si l'objectif que l'on emploie est bon au point de vue optique, c'est-à-dire ne déforme pas irrégulièrement les images, tous les diamètres du Soleil et de *Vénus* seront également altérés, et la position du centre des deux astres ne sera nullement changée ; la mesure des angles de position devra donc, en théorie, donner des résultats indépendants de toutes les causes d'erreur signalées. Mais on rencontre, dans la pratique, de très-grandes difficultés à obtenir, avec le degré d'exactitude requis par le calcul, une direction fixe servant d'origine aux angles de position. Les expéditions américaines sont, à ma connaissance, les seules qui aient cherché à résoudre le problème ; il est donc nécessaire, pour apprécier la méthode, d'attendre la publication et la discussion de leurs résultats.

2°. *Mesure de la distance des centres.*—La position du centre des deux astres n'est aucunement modifiée, nous l'avons vu, par les phénomènes de diffraction qu'introduit dans l'image un système optique supposé parfait. La mesure de la distance des centres doit donc, théoriquement, inspirer toute confiance, comme celle des angles de position. L'expérience, du reste, semble prouver que les dimensions d'appareils et le mode opératoire des missions françaises peuvent donner la distance des centres avec le degré d'exactitude requis par le calcul.*

Mais il y a, dans ce procédé, une difficulté de même ordre que celle qui consistait, dans le précédent, à déterminer l'origine des angles de position, c'est la nécessité de connaître la *valeur angulaire* des images. Les images focales sont mesurées en unités de longueur ; mais, pour pouvoir comparer entre elles les épreuves obtenues dans les différentes stations, il faut connaître quel angle représente, dans le ciel, un millimètre mesuré sur l'épreuve, ou, ce qui revient au même, sous quel angle on voit, du centre optique de l'objectif, un millimètre placé au foyer. On peut, du reste, déterminer cette valeur de bien des manières différentes :

* On se rappelle que les photographies des missions françaises étaient obtenues directement au foyer d'un objectif d'environ $3^{m}\cdot80$ de foyer. Sur les images directes, sans grossissement, le diamètre du Soleil est d'environ $35^{mm}\cdot84$ et celui de *Vénus* de $1^{mm}\cdot15$. Les images étaient obtenues en outre sur plaques daguerriennes.

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la première consiste à mesurer exactement la longueur focale de l'objectif employé (procédé suivi par les Américains) ; on peut encore placer au foyer de l'instrument un micromètre à fils, ou une plaque de verre divisée, et noter le temps qu'une étoile connue met à franchir une distance donnée, quand l'appareil reste fixe. Mais il paraîtra préférable de déterminer la valeur angulaire des images par des procédés purement photographiques. On pourra, par exemple, collimer l'instrument photographique par une lunette méridienne, et photographier ainsi le réticule de cette dernière, dont les fils sont à des distances parfaitement connues. Enfin un procédé employé depuis longtemps par M. Rutherford, et qui lui donne d'excellents résultats, consiste à diriger à former sur la plaque photographique au foyer de l'instrument rigoureusement immobile l'image d'une étoile brillante. Cet astre laisse alors une trace lumineuse continue ; la longueur de cette trace, et le temps pendant lequel elle a été obtenue, permettent de déterminer aisément la valeur angulaire de l'instrument. On peut encore remplacer dans cette méthode l'étoile par le Soleil ; il faut alors, l'appareil restant immobile, prendre deux images du Soleil à un intervalle de temps parfaitement connu, et mesurer la distance des centres de ces deux images. Il est nécessaire, dans ce cas, que les deux images n'empiètent pas l'une sur l'autre ; alors les diamètres du Soleil seraient modifiés dans toute la partie commune aux deux images. J'ai montré, en effet, dans mon premier travail, que les images sont, en général, plus petites lorsqu'elles se forment sur un champ déjà impressionné par la lumière.

Il est, enfin, un dernier procédé qui paraît irréprochable au premier abord, mais qui, dans la pratique, conduirait à des erreurs notables. J'ai montré, en opérant sur des objets uniformément éclairés, à bords rectilignes, et de dimensions très-supérieures à la zone de diffraction, que l'augmentation de l'image d'un objet lumineux est égale à la diminution de celle d'un objet obscur dans les mêmes circonstances. La somme de ces dimensions était constante et égale à ce qu'elle devrait être si l'image se formait seulement d'après les lois de l'optique géométrique (voir la première partie). S'il en était rigoureusement de même pour le Soleil et *Vénus*, les diamètres de ces deux astres, variables en sens inverse d'une épreuve à l'autre, donneraient une somme constante. Cette somme pourrait servir de facteur de réduction pour comparer entre elles les épreuves des différentes stations, et il suffirait dès lors de déterminer la valeur angulaire d'un seul instrument : le rapport des sommes des diamètres de Soleil et de *Vénus*, dans deux instruments, serait celui de leurs valeurs angulaires.

Malheureusement on ne peut compter sur la constance de cette somme, et cela pour plusieurs raisons :

1°. Le diamètre de *Vénus* est loin d'être grand par rapport à l'étendue de la zone diffractée. La théorie montre alors que la diminution du diamètre de *Vénus* n'est pas la même que celle

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qui se produirait pour un bord rectiligne; le Soleil, au contraire, a une courbure assez faible pour pouvoir être considéré comme un bord rectiligne.

2°. L'intensité lumineuse des différents points du Soleil n'est pas du tout uniforme; elle décroît rapidement vers les bords, par suite de la convexité et de la nature physique de cet astre. Cette décroissance est même tellement accusée que l'intensité photogénique des bords paraît inférieure à celle de la pénombre des taches. Pendant la durée du passage *Vénus* se projettera donc en un point du Soleil beaucoup plus lumineux que n'est le bord, et dont l'intensité varie sans cesse à mesure que *Vénus* se déplace sur le Soleil. L'augmentation du Soleil est alors différente de la diminution de *Vénus*, et la somme de leurs diamètres est variable avec toutes les conditions de l'expérience, sensibilité de la plaque, durée de pose, transparence de l'atmosphère au moment ou l'on fait la photographie, etc.

Toutes ces prévisions ont été confirmées par l'expérience directe à l'appareil à passages artificiels, et, mieux que tout le reste, la mesure des épreuves du passage même de *Vénus*, obtenues dans tous les pays et dans les circonstances les plus variées, doit mettre ces causes d'erreur en évidence et montrer que, pour déterminer la valeur angulaire des instruments, il faut avoir recours à l'une des méthodes que j'ai exposées plus haut, en renonçant complètement à la constance présumée de la somme des diamètres des deux astres.

II. *Détermination de l'Instant des Contacts.*

La détermination de l'instant des contacts, qui peut être tentée par la photographie pour contrôler l'observation directe s'obtient de deux façons différents, soit par l'observation du contact même, soit interne, soit externe, des deux disques, soit par la mesure de la corde commune à *Vénus* et au Soleil au moment où la planète entre sur le bord de l'astre. En étudiant comment varie, avec le temps, cette *distance des cornes* ou corde commune, on en déduit par extrapolation le moment où cette distance est nulle, c'est-à-dire le contact. Comme les causes d'erreur qui s'attachent à ces deux procédés sont les mêmes nous les réunirons pour la discussion.

La théorie de la diffraction permet de calculer toutes les phases du passage de la planète sur le bord du Soleil dans un cas simple, celui où l'on suppose que *Vénus* est formée par un disque ou par une sphère opaque sans atmosphère, et que le Soleil a une intensité lumineuse constante en chacun de ses points. On trouve de la sorte que, dans l'intérieur même de la partie géométrique de l'image, l'intensité décroît quand on s'approche des bords, et forme une zone estompée qui s'étend bien en dehors de l'image

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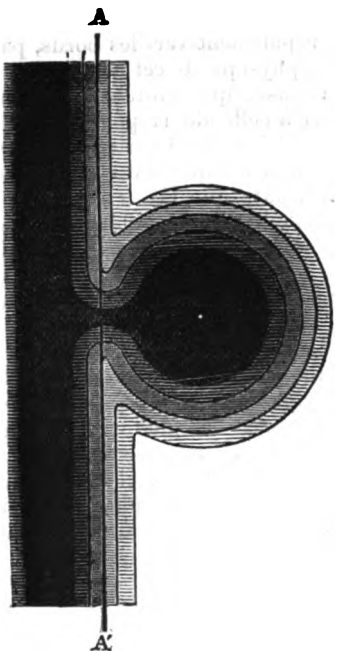
géométrique. On peut ainsi obtenir par points une série de *courbes de niveau*, pour ainsi dire, tout le long desquelles l'intensité lumineuse est constante. La figure ci-jointe représente grossièrement la forme générale de ces courbes au moment même du contact géométrique interne. La courbe AA′, tout le long de laquelle l'intensité est la moitié de ce qu'elle est au centre du Soleil, se confond avec le bord géométrique de cet astre pour tous les points un peu éloignés du point de contact; dans les régions de *Vénus* distantes du même point, la courbe est concentrique à l'image géométrique et un peu intérieure (elle ne coïncide plus avec le bord géométrique à cause de la courbure de *Vénus*); enfin, aux environs du point de contact, ces deux courbes se raccordent de façon à reproduire exactement l'apparence désignée sous le nom de goutte noire ou de ligament. Cette apparence est exagérée encore dans les courbes d'intensité $\frac{1}{4}$ et $\frac{1}{8}$ que représente également la figure. On obtient des traces analogues pour chaque instant du passage.



D'autre part, une plaque photographique, exposée à la lumière pendant un temps déterminé, donne une image qui comprend tous les points dont l'intensité lumineuse est supérieure à une certaine limite. L'impression s'arrête à une de ces courbes de niveau que j'ai indiquées plus haut, et comprend des courbes de niveau de plus en plus faibles, à mesure que l'on augmente la sensibilité de la plaque, l'intensité de la lumière, et la durée de pose.

Ce sont justement les conditions dans lesquelles ont été obtenues mes photographies. L'appareil à passages artificiels était amené à une position convenable, puis fixé, et on faisait sur la même plaque cinq épreuves successives, correspondant à des durées de pose progressivement croissantes. On obtient ainsi la forme de cinq courbes de niveau de plus en plus faibles, et il est frappant de voir avec quelle fidélité l'expérience réalise les formes indiquées par la théorie. La même expérience a été répétée en donnant à la planète les positions qu'elle occupe de dix en dix, ou de quinze en quinze, secondes pendant les cinq minutes

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qui précèdent le contact interne d'entrée et pendant les deux minutes qui le suivent.

Des résultats analogues avaient déjà été partiellement, du reste, obtenus à Greenwich et par M. Janssen, dans les expériences préliminaires faites avant le départ des expéditions pour le passage de *Vénus*: on avait quelquefois observé des apparences de goutte noire quand l'appareil à passages artificiels était éclairé très-fortement par la lumière directe du Soleil, par exemple.

Reste à déterminer l'erreur que ces phénomènes peuvent introduire dans l'observation photographique de l'instant des contacts, surtout des contacts internes. Or, la théorie montre que l'apparence générale ne change pas brusquement au moment des contacts. Même alors que la planète est entièrement entrée sur le Soleil, l'apparence de la goutte noire persiste tant que le filet lumineux compris entre *Vénus* et le bord du Soleil n'a pas une dimension égale ou supérieure à celle de la zone de lumière diffractée. Il sera donc possible d'obtenir encore une *goutte noire* après que le contact géométrique aura eu lieu: il suffira, pour cela, de poser très-peu de temps.

La photographie a, dans cette observation, un désavantage considérable sur l'observation optique directe. L'œil, en effet, à côté d'une lumière très-vive, comme celle du Soleil, devient incapable de percevoir des intensités assez faibles: la perception optique s'arrêtera donc généralement à des courbes de niveau peu distantes du bord géométrique, tandis qu'en augmentant la sensibilité des plaques photographiques ou la durée de pose, on ira chercher des courbes d'intensité aussi faible que l'on voudra. Dans l'observation du passage, même avec des plaques identiques et une durée de pose constante, il suffira du moindre changement dans la transparence de l'atmosphère pour que l'impression photographique s'arrête à des courbes de niveau différentes, et que de deux épreuves successives la dernière semble correspondre à une période antérieure du phénomène. Les effets indiqués diminuent si l'on augmente l'ouverture de la lunette, mais ils croissent considérablement pour peu que l'objectif employé possède la moindre aberration. Avec un objectif non rigoureusement aplanétique, j'ai pu obtenir encore un contact apparent par des durées de pose très-faibles, alors que *Vénus* était complètement entrée sur le Soleil depuis *une minute* de temps.

Quant aux contacts externes, la diffraction modifie la forme de l'échancrure que *Vénus* produit sur le Soleil; mais, comme il s'agit seulement de constater la présence de cette échancrure, il est possible que l'observation photographique donne des résultats de même valeur que l'observation optique.

Reste un dernier moyen, qui consiste à étudier comment varie, avec le temps, la corde commune à *Vénus* et au Soleil, pendant l'entrée ou la sortie, et à en déduire par extrapolation le moment où cette corde est nulle, c'est-à-dire les contacts. Ce

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procédé présente, en photographie, des difficultés particulières, puisque pour un même instant la longueur de la corde peut varier entre des limites considérables avec la sensibilité de la plaque, la durée de pose, ou la transparence de l'atmosphère.

Toutes ces conclusions, vérifiées directement par l'expérience, sont déduites de l'hypothèse d'un planète sans atmosphère, et de l'égale intensité lumineuse des différents points du Soleil; mais on doit reconnaître que le phénomène réel est encore plus complexe. Nous espérons pouvoir, M. André et moi, déterminer expérimentalement les modifications que la présence d'une atmosphère autour de *Vénus* amène dans les résultats auxquels nous conduisent nos premières expériences.

En résumé, l'observation photographique du passage de *Vénus* présente des difficultés au moins aussi grandes que l'observation optique; mais on peut conserver tout espoir d'arriver par ce moyen à une bonne détermination de la parallaxe, surtout si l'on emploie les méthodes de mesure de distances de centres et d'angles de position, méthodes propres à la photographie. En tous cas, le prochain passage de *Mercure* (Mai 1878) devra être observé avec le plus grand soin, afin de vérifier d'abord sur un phénomène céleste nos conclusions, basées sur des expériences de passages artificiels, et d'assigner ensuite exactement les limites entre lesquelles les causes d'erreur signalées peuvent varier dans la nature.

A Determination of the Semi-diameter of Venus at the mean distance of the Sun from the Earth. By A. W. Downing, B.A.

In this investigation I have made use of the results of the Washington Transit Circle Observations during the years 1866–1872 inclusive; the Transit Circle having been brought into use in 1866, and the results of 1872 being the most recent to which I have access. During this interval the value of the semi-diameter of *Venus* at the mean distance of the Sun from the Earth, given in the American Ephemeris, and with which the Washington Observations have been compared, was $8''{\cdot}546$.

Let the true semi-diameter $= 8''{\cdot}546\ (1+y)$, so that $y =$ coefficient of variable part of correction depending on the planet's distance; and let $x =$ constant part of correction arising from irradiation &c.; we have then a series of equations of the form

$$x + y \times \text{Tab. Semi-diameter} = \text{Correction to Ephemeris.}$$

Using all the observations of vertical diameter of *Venus* made during the above-mentioned years, I have formed 167

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equations in this manner; solving these by the method of least squares, I obtain the equations—

$$167x + 1636{\cdot}3y = 40{\cdot}3$$
$$1636{\cdot}3x + 23565{\cdot}24y = 239{\cdot}11;$$

whence

$$x = 0{\cdot}4439 \pm 0{\cdot}1036 \times e,$$

where e is the probable error of an observation, and

$$y = -0{\cdot}02068 \pm 0{\cdot}00777 \times e.$$

Therefore

$$\text{True Semi-diameter} = 8''{\cdot}546\,(1+y) = 8''{\cdot}3693 \pm 0{\cdot}0664 \times e.$$

The value $8''{\cdot}546$ was determined by Prof. Peirce from 30 observations made with the Washington Mural Circle during the year 1846.

22 *Waterloo Road, Dublin,*
1877, *May* 9.

Second Catalogue of Micrometrical Measurements of Double Stars made at the Temple Observatory. By J. M. Wilson, M.A., and G. M. Seabroke, Esq. (Abstract.)

This Catalogue contains the measures made at the Temple Observatory during the years 1875 and 1876, and some few measures made in previous years that were omitted in our first Catalogue.

Most of the measures were made by Mr. Seabroke, Mr. Wilson having been unable to work at the Observatory during 1875 and part of 1876. Mr. Seabroke's measures were, however, frequently confirmed by those of Mr. Percy Smith. They were all made with the parallel wire micrometer, and a magnifying power of about 400 on the Alvan Clark refractor of 8¼ inches.

The Temple Observatory is now being built in a permanent form, with a Curator's house adjoining, and we take this opportunity of a break in our series of measurements to offer this second Catalogue to the Society, in the belief that double-star measures are more valuable when published at frequent intervals.

We thought it unnecessary to print the R.A. and Dec. of Struve's stars. All observers who are likely to use this catalogue will have them at hand.

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Lunar Eclipse of the 27th February, 1877, observed at Cadiz.
By Augusto T. Arcimis.

I have long delayed reporting my observations of this eclipse because I even doubted the reality of what I had seen, but having read in the scientific journals that the phenomenon had everywhere presented a similar aspect, I venture to offer the result of my observations, which can no longer be received with doubt or mistrust.

The Sun set at $5^h\ 35^m$. The clouds which gathered in the east prevented my seeing the Moon until $6^h\ 20^m$; it was already eclipsed, and in spite of the crepuscular light, the characteristic copper tint was, though faintly, visible in the centre of the disk, the other portions being covered by the clouds.

At $6^h\ 46^m$ the Moon is red throughout to the naked eye and presents the appearance, were that possible, of an annular eclipse; the centre is dark and not a single detail of its surface is distinguishable; it is surrounded by a luminous fiery corona. This strange aspect disappears through the telescope, and the eclipse presents the normal appearance.

The clouds now and then interrupt the observation.

At 7^h the red ring breaks towards the south, and the inroad of the shadow becomes distinctly visible to the naked eye. Through the telescope only the western edge, surrounded by the penumbra, can be distinguished, while the rest of the disk presents a dull grey colour so deep that it effaces every detail of the lunar surface.

The clouds again invade the sky.

At $7^h\ 41^m$ it clears partially, and the crater *Grimaldi* emerges from the shadow.

At $7^h\ 49^m$ emersion of *Kepler*.

At $7^h\ 57^m$ „ „ *Kopernicus*.

At $8^h\ 0^m$ the shadow crosses the centre of *Plato*.

At $8^h\ 1^m$ emersion of *Tycho*.

At $8^h\ 5^m$ „ „ *Archimedes*.

At $8^h\ 7^m$ „ „ *Ptolemeus*.

At $8^h\ 11^m$ „ „ *Manilius*.

At $8^h\ 15^m$ „ „ *Menelaus*.

At $8^h\ 21^m$ the line of the shadow reaches the crater *Endymion* and the edge of *Mare Australe*.

At $8^h\ 28^m$ the shadow touches the edge of *Mare Crisium*.

At $8^h\ 36^m$ the last contact takes place at 90° from the boreal pole towards the west.

This eclipse presented a notable aspect, and the corona of red light which spread over the internal edge of the Moon elicited the admiration even of strangers to the science. An unforeseen circumstance prevented my using the spectroscope.

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A Table for facilitating the determination of Mean Equinoctial Time to the end of the present Century.

By Vice-Admiral Sir Charles Shadwell.

In the *Nautical Almanac*, from the year 1834 (the date of its first appearance in its present improved form) up to 1875 inclusive, information was formerly given, at page 20 of each month, to facilitate the determination of 'Mean Equinoctial Time.'

From and after 1876 this information has been altogether discontinued. No reason has been assigned, either in the 'Annual Prefaces' or in the 'Explanations' of that volume, for this omission. It is, however, understood to have been withdrawn because it had never come into general use among astronomers, as had been anticipated at the time of its first introduction.

Since the use of equinoctial time afforded a means of reckoning time free from the necessity of specifying any particular geographical locality, being measured from an epoch common to all the world (viz. the passage of the mean Sun through the mean vernal Equinox) and identifiable independently of all localities, thus avoiding all ambiguities in its description, its disappearance from the pages of the National Ephemeris is, I think, to be regretted.

With a view to rectify this omission to a certain extent, and to afford those desirous of employing equinoctial time the means of doing so in future, the accompanying Table, giving the data for its determination up to the end of the present century, is herewith submitted to the notice of the Royal Astronomical Society:—

Table for facilitating the determination of Mean Equinoctial Time.

Equinoctial Year.	Date of Commencement.	Number. N.	Fraction of Equinoctial Time for the Year to be added to the Equinoctial Day.
	March.		d
1875–76	22	81	0·574169
1876–77	21	81—80	0·331953
1877–78	21	80	0·089737
1878–79	22	81	0·847521
1879–80	22	81	0·605305
1880–81	21	81—80	0·363089
1881–82	21	80	0·120873
1882–83	22	81	0·878657
1883–84	22	81	0·636441
1884–85	21	81—80	0·394225

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Equinoctial Year.	Date of Commencement. March.	Number. N.	Fraction of Equinoctial Time for the Year to be added to the Equinoctial Day. d
1885–86	21	80	0·152009
1886–87	22	81	0·909793
1887–88	22	81	0·667577
1888–89	21	81—80	0·425361
1889–90	21	80	0·183145
1890–91	22	81	0·940929
1891–92	22	81	0·698713
1892–93	21	81—80	0·456497
1893–94	21	80	0·214281
1894–95	22	81	0·972065
1895–96	22	81	0·729849
1896–97	21	81—80	0·487633
1897–98	21	80	0·245417
1898–99	21	80	0·003201
1899–1900	22	81	0·760985

Explanation of the Table.

This Table contains for the equinoctial years named, that is for the years 1875–76 to 1899–1900 inclusive, 1st, in column 2, the day on which the equinoctial year commences; 2ndly, in column 3, the number N; 3rdly, in column 4, the fraction of equinoctial time to be added to the day of the equinoctial year.

N is the number of days which is to be subtracted from the 'day of the year' (increased if necessary by 365) to give the corresponding day of the equinoctial year; the day of the year corresponding to any given date being taken from the Table published annually in the *Nautical Almanac* commencing with 1876 ('Day of the Year,' &c., pp. 484 &c.)

This number is generally 81, but sometimes 80. When both numbers are given, 81 is to be subtracted from the day of the year between the vernal Equinox and December 31, and 80 between January 1 of the following year and the succeeding Equinox.

Application of the Table.

I. To find when the equinoctial year commences:—

To the date in column 2 add the complement to unity of the fraction in column 4.

Thus the equinoctial year 1884–85 commences on March $21^d + (1 - 0{\cdot}394525)$, or on March $21^d{\cdot}605775$ Greenwich Mean Time.

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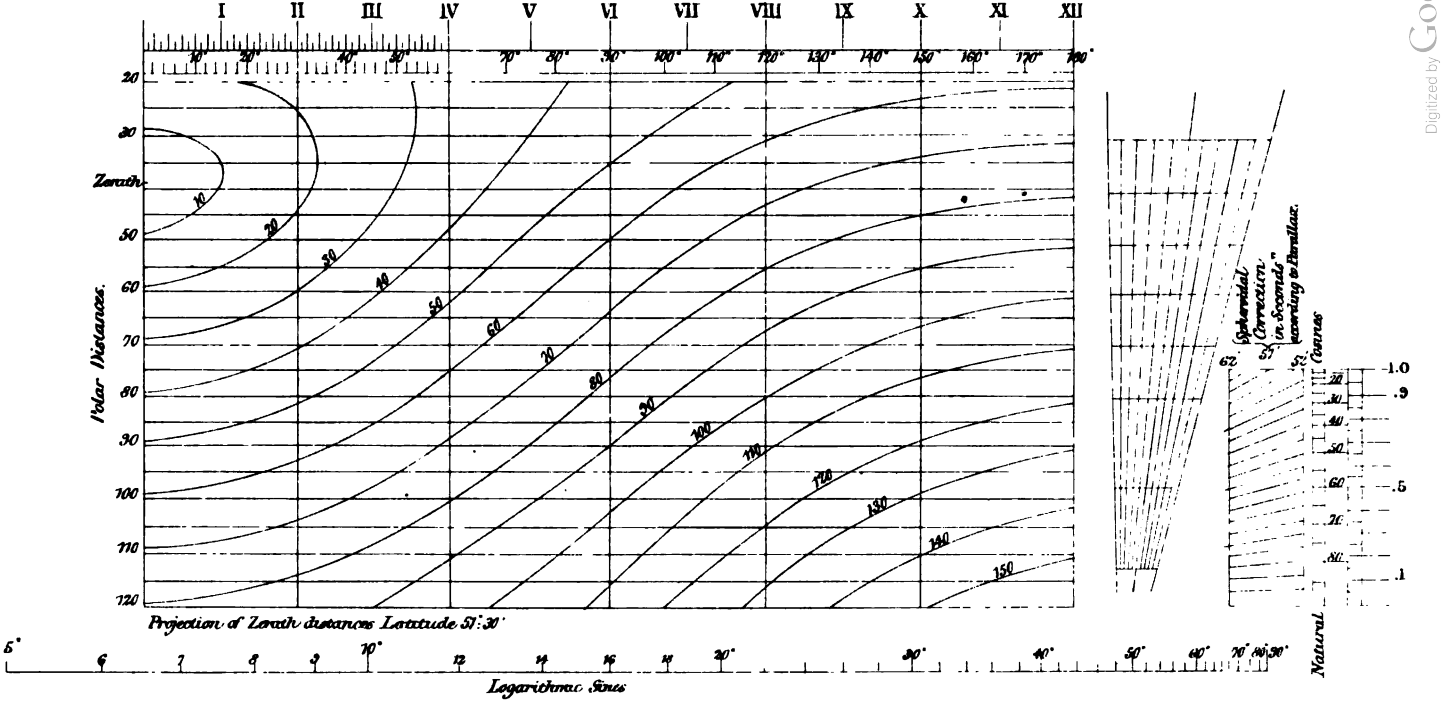

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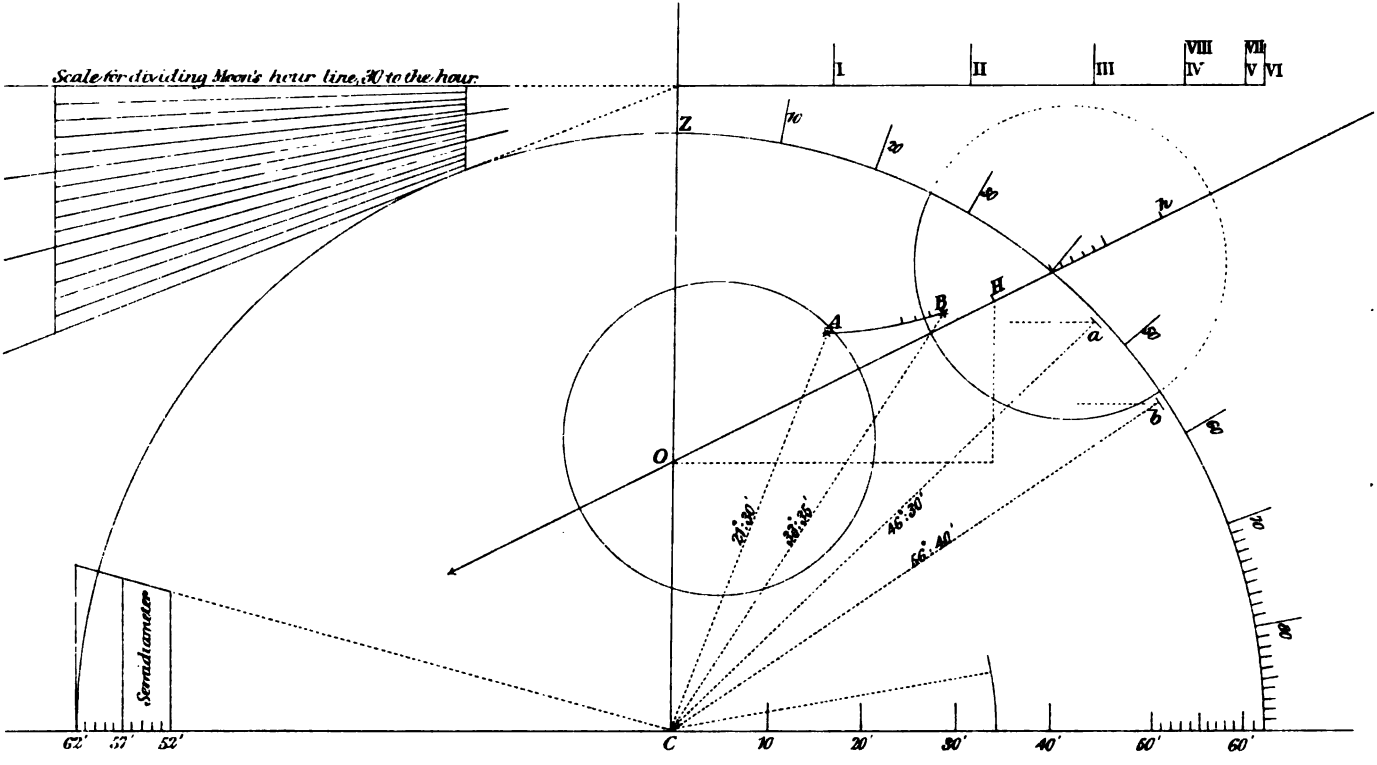

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So again the equinoctial year 1894–95 commences on March $22^d+(1-0\cdot972065)$, or on March $22^d\cdot027935$ Greenwich Mean Time.

II. To find the mean equinoctial time corresponding to Greenwich mean noon on any given day:—

From the day of the year, increased if necessary by 365, subtract the number N, and affix the fraction for the year from column 4.

Thus: Required the equinoctial time at Greenwich mean noon on May 13, 1878.

Here the day of the year corresponding to May 13 would be 132, and in the equinoctial year 1878–79 N is 81, and the fraction of equinoctial time $0^d\cdot847521$.

Therefore, $132^d-81^d+0^d\cdot847521$; or $1878^y\ 51^d\cdot847521$ is the mean equinoctial time at Greenwich mean noon on the day in question.

Again; What will be the equinoctial time at Greenwich mean noon on February 5, 1893?

The day of the year corresponding to February 5, 1893, is 35, and in the equinoctial year 1892–93, N between January 1 and the following vernal Equinox is 80, while the fraction of equinoctial time to be added is $0^d\cdot456497$.

Hence, $35^d+365^d-80^d+0^d\cdot456497$, or $320^d\cdot456497$, is the mean equinoctial time at Greenwich mean noon on February 5, 1893, which is required.

Note.—Should it ever be deemed expedient to reintroduce "mean equinoctial time" to a place in the *Nautical Almanac*, it would not be necessary to assign to it a column in a page for each month, as under former arrangements previous to 1876. All that would be requisite would be to give, in a note at the foot of the Table "Day of the Year, &c.," the number N and the fraction of equinoctial time to be employed, both before and after the vernal Equinox of the current year, with a brief explanation of how they were to be applied; this last being given in the "Explanation of the Articles" at the end of the work.

A very slight alteration of the present arrangement of the type in the Table referred to, and a corresponding brief addition to the "Explanation," would permit this.

Meadowbank, Melksham,
1877, April.

Description of an Improved Diagram for the Graphical Solution of Spherical Triangles, applicable to the questions arising out of the Spheroidal Figure of the Earth, treated in the Paper read before the Society Nov. 10 ult., and further illustrated by the case of the Prediction of Occultations. By F. C. Penrose, Esq.

The Table, which should have accompanied the paper referred to, giving the values of n—namely the distance between the centre of the Earth and the foot of the normal in different latitudes—and

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for the correction of the Tabular Parallax when referred to the same point, is as follows. The Horizontal Equatoreal Parallax is taken as equal 57′. When more or less than this, the figures below should be adjusted proportionably :—

Latitude.	Correction to Polar Distance. Subtract from P.D.	Correction to the Equatoreal H.P. Add to H.P.
	"	"
0	0	0
5	2·01	0·10
10	4·01	0·35
15	5·97	0·80
20	7·89	1·34
25	9·74	2·06
30	11·52	2·88
35	13·22	3·80
40	14·81	4·75
45	16·29	5·76
50	17·64	6·76
55	18·85	7·72
60	19·93	8·60
65	20·85	9·40
70	21·61	10·15
75	22·21	10·70
80	22·65	11·15
85	22·90	11·40
90	22·99	11·49

The diagram attached to the paper referred to, although it answers its purpose sufficiently well for working the spheroidal corrections, is not so well adapted for the general solution of a spherical triangle, because the lines representing the different zenith distances diverge so much from one another that it becomes troublesome to interpolate, and it offers but little facility for the converse problem of obtaining altitudes from given hour angles and polar distances; moreover, when the angle at the Moon is small, it does not suffice for determining the angle with sufficient accuracy.

The new diagram avoids these imperfections. The arrangement of the lines due to the different zenith distances is much more equable, so that interpolations can be effected with tolerable certainty.

This also applies to the interpolations required for using a diagram prepared for a particular latitude for latitudes within a few degrees of it.

If diagrams similar to the one submitted were made for every fifth degree of latitude, they would suffice, as I find by trial,

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within limits of error of about 30′, to determine any zenith distance from a given hour angle and polar distance, or for performing the converse operation of finding the hour angle or polar distance from the other two given data: and with more accuracy, of course, if a larger scale were adopted. I exclude, of course, unfavourable cases; such, for instance, as are produced by ill-conditioned triangles, which would even be avoided when logarithmic calculation is used.

This diagram belongs to latitude 51° 30′, and is, in fact, a projection of a sphere on a method not much unlike that of Mercator. It gives the relation between the three sides of a spherical triangle and one of the angles. Two of the sides and the angle may vary indefinitely, but one side is constant for the particular diagram. The angle referred to is adjacent to the constant side. For instance, if the constant side be supposed to be the co-latitude, the vertical measurements give polar distances and the oblique curved lines give zenith distances; but for general use I speak of the latter as the base, and the former as the side, and of the angle as the included angle—that is, included between the constant and the variable side. For instance, it will be seen by inspection of the diagram, that if we combine the vertical line drawn downwards from VI^h or 90° on the upper horizontal row of figures with 50° drawn across from the vertical column on the left, they will meet very near to the oblique line representing the base 60°. This, using the notation given above, is stated thus:—

The side 50° and included angle 90° have approximately for their base 60°. (This is true for 59° 48′.)

In a lunar triangle, we may thus obtain approximately the zenith distances of the Moon and star, and the parallactic angles of the two bodies. For this purpose generally two diagrams will be necessary, one adapted to the latitude and the other to the lunar distance. The following case, however, has been chosen as adapted to the one diagram herewith submitted.

In the figure below, if PSM, PZM be supposed to represent the measurements requisite for a lunar distance observation, the observer may be supposed to know

PZ	The co-latitude;
PM	The Moon's polar distance, by computation;
PS	The star's „ „
SM	The lunar distance, by measurement;
ZPM	The Moon's hour angle, by computation;
ZPS	The star's „ „

What are required are the two parallactic angles, viz. ZSM and ZMS, and the sides ZM and ZS, and also the angle PMS. The two sides indeed may, under favourable circumstances, be observed; but it is often impossible or inconvenient to do so. The diagrams enable all these quantities to be obtained by inspection with sufficient accuracy for general purposes, and,

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should more exactness be required, the solution by this means offers a valuable check.

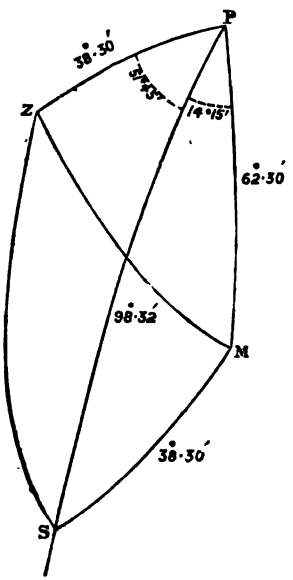
Thus all the data required for clearing the lunar distance may be determined.

Should the azimuth be required, it may be got, *mutatis mutandis*, as readily as the parallactic angle.

The simplest way of disposing of the spheroidal correction is by at once referring both the observation and the lunar triangle to the foot of the normal. When this is done, the geocentric lunar distance given in the three-hourly Arguments of the *Nautical Almanac* is, for any other latitude than the equator, too large or too small according as the angle PMS is acute or obtuse, and the excess or defect $= n \cos D \cos M$, where n is the quantity given above in the Table for the correction of the Moon's declination, and M is the angle PMS.

It seems, however, on several accounts more convenient to make this adjustment upon the measured distance, instead of the tabular argument, but in the contrary direction, so that when M is acute the distance must be increased, and decreased when it is obtuse, by the amount above stated.

As respects the increment to the parallax given in the Table, it should receive its due proportion when the parallax in altitude is computed.



As an example of reducing a lunar distance with the help of the diagram, let it be supposed that the altitudes have not been measured, but the distance only.

Then, in the lunar triangles PZM, ZMS, after computing the hour angles and polar distances of the Moon and star, we have—let us suppose—

		°	′
PZ	=	38	30
PM	=	62	30
SM	=	38	30
PS	=	98	32
SPM	=	14	15
SPZ	=	51	45

In the spherical triangle PMS the use that is made of the given side SM is in the selection of the proper diagram, and the same applies to the use of the side PZ in the spherical triangle PZS.

Then, combining 62° 30′ as a side with 98° 32′ as a base, we obtain the included angle 157°. This is the angle PMS.

Then, in triangle PZS, using 98° 32′ as a side and 51° 45′ as an included angle, we obtain for the base PS 74° 30′.

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Then, in triangle PZM, using 62° 30′ as a side and ZPS + SPM = 66° as an included angle, we get for the base 54°.

Then, in triangle ZSM, with 74° 30′ as a side and 54° as a base, we obtain the star's parallactic angle ZSM = 50° 30′; and lastly, in the same triangle, using 54° as a side and 74° 30′ as a base, we obtain ZMS, the Moon's parallactic angle = 112°.

The corrections may now be made.

	″
The effect of the increased value of parallax in altitude = 7″ sin 54° cos 112°, increasing the distance by .	2·1
But the distance must be decreased, on account of the term $\pi \cos D \cos PMS$, by	15·3
Total correction	13·2

This example is not an imaginary case, but would have occurred in latitude 51° 30′ S. and longitude $4^h\ 34^m$ W. on Feb. 9th ult. in the distance of *α Aquilæ* given in the *Nautical Almanac*. As the parallax then was 54′, the amount above given must be reduced to 12″·6. But this quantity would have affected the longitude by 52^s, and by more than 8 nautical miles in distance. And this is by no means an extreme case.

I showed in the former paper how this approximate determination of the altitudes and angles, &c., might serve to facilitate the accurate clearing of the lunar distance. I will proceed to show how it can be used to assist in predicting occultations and eclipses. At the bottom of the diagram is added a scale of logarithmic sines similar to that used on the slide rule, which will enable opposite sides or angles to be ascertained without recourse to another diagram.

As an example of its use, take the figure already given, and in the triangle PZM let it be required to find the angle PMZ. Since log sin PMZ − log sin PZ = log sin ZPM − log sin ZM, the difference on the logarithmic scale between PMZ and 38° 30′ must equal the distance between ZPM and ZM. Measure then the interval between 66° and 54° on this scale and apply it to 38° 30′, and it will be found to reach to 45°, which is very nearly the true result. It should be observed that when the angles approach 90° this scale is not suited for accurate determination. At such points, however, the diagrams are at their maximum of efficiency.

For the purpose of predicting occultations, an additional diagram is prepared with certain requisite scales, especially one of minutes of arc for different values of parallax. It is suitable to all latitudes.

Having prepared the proper elements, lay down the Moon's course on the occultation diagram, and, with the hour angle and polar distance, find, on a diagram of zenith distances suited to the latitude, the zenith distance and parallactic angle at the moment of conjunction: the former is required for ascertaining the amount of the Moon's parallax in altitude, and the latter for its direction with reference to the point C, which represents the

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centre of the earth, or rather the foot of the normal belonging to the latitude.

When the position of the place for which the prediction is made is laid down for the moment of conjunction, it is seldom difficult to decide in what part of the Moon's path the phenomenon is to be looked for *within an hour*. Make, then, a new computation of the parallax in altitude and the parallactic angle, and lay down and join the points which have been determined. A scale is given for dividing any hourly segment of the Moon's path into 30 subdivisions, and there is little difficulty in dividing a corresponding hour interval on the line joining the two places of the terrestrial observatory [a segment always of an elongated ellipse, and which, it may be observed, is generally concave for north and convex for south declinations] into intervals representing 10^m each. It is now easy to see which of the corresponding intervals are separated most nearly to the extent of the Moon's semidiameter, and what minute of time offers the best prediction. An example is given, namely, a prediction of the occultation of ρ *Leonis* Jan. 30, 1877, for Greenwich.

Elements of Occultation. ρ *Leonis*, Jan. 30, 1877.

Prediction for Greenwich.

		✱'s R.A.	✱'s Dec. approx.	Geocentric diff.
	h m s	h m s	° ′	′ ″
G.M.T. of ♂	12 5 11	10 26 22	9 56	27 36
	0 1 59			−0 18 to normal.
	20 39 18			27 18
G.S.T. of ♂	8 46 28			

Hour angle $1^h\ 40^m$ — Parallax.

Observer west of Moon. — geocentric 60 52

+ 0 7

60 59

	′	″
Moon's Motion in R.A.	34	10
Eastwards	33	50
And in Decl. southwards	16	8

With these measures of the Moon's motion lay down the Moon's course upon the occultation diagram, and HO will be the Moon's course during the hour preceding conjunction; and with the hour angle and declination above given obtain from the general latitude diagram, using them as an included angle and side, the zenith distance at conjunction.

	°	′
This appears to be	46	30
The logarithmic sine scale will then give the parallactic angle, about	21	30

The parallax 60′ 59″ set off upon a radius drawn at an angle of 46° 30′ from CZ will reach to *a*.

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The horizontal distance from *a* to ZC will be the parallax in altitude.

Set this off as CA, making an angle of 21° 30′ with CZ.

A is the observer's place at conjunction.

It is at once evident that the Moon's disappearance must have taken place more than an hour before conjunction. Take, then, an hour angle of $3^h\ 10^m$ or $1\frac{1}{2}$ hours before ☌, and with this as an included angle, and with the star's polar distance as a side, rework the observer's place. This will now be found to have

Zenith distance about 56° 30

and

Parallactic angle . 33 35

With these measures determine C*b* and CB in the same manner as C*a* and CA were done before. B is then the observer's place $1\frac{1}{2}$ hours before conjunction. Join AB—remembering that it is a portion of an elongated ellipse. Measure backwards upon the Moon's course $Hh = \frac{1}{2}$ HO, and *h* becomes the Moon's place corresponding to B. By means of the diverging scales on the drawing, the line AB may be divided into 9 divisions each measuring 10 minutes, and H*h* into 15 divisions each measuring 2 minutes. Having marked off as many of these divisions as may seem requisite, take the Moon's semidiameter suited to the parallax 60′, and it will be found to reach across and bridge the interval between the two points on the lines H*h* and AB due to the time $1^h\ 14^m$ approximately before conjunction. By working in a similar manner the interval for the reappearance, it might be shown to agree most nearly with the time 8 minutes before conjunction;

These Greenwich times therefore are 10 51

and 11 57

These predictions are identical with those given in the *Nautical Almanac*, but are quite independent of it.

If the angle at the Moon's vertex for the observation is required, join the centre C with the observer's place at the time of the phase in question, and having drawn a circle representing the Moon, draw a straight line through its centre parallel to the former one. It will cut the Moon's circumference at the proper points for estimating the angle required. The figure gives the erect image, and must be allowed for accordingly when required for the inverted image.

On a Method of Destroying the Vibrations in a Mercurial Reflector.

By M. de Boë, of Antwerp.

(*Communicated by Capt. Wm. Noble.*)

M. de Boë (Anvers) pense avoir perfectionné le système d'observation des fils de la lunette méridienne sur le bain de mercure.

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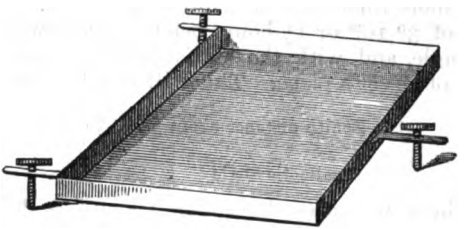
Il emploie une cuvette à trois vis calantes, au fond de laquelle il place une plaque daguerrienne, sur laquelle il laisse tomber quelques gouttes de mercure. A l'aide de ce procédé les vibrations sont à peu près complètement annulées.

La cuvette est à fond plan.



Avant de laisser tomber le mercure sur la plaque daguerrienne, on la frotte avec le doigt et un peu de mercure ; alors le fond du liquide devient plus adhérent, ce qui est la principale cause qui empêche les vibrations.

It will be seen that the method of M. de Boë is merely a modification of that described by Prof. Pritchard before the Roya Astronomical Society. (*Monthly Notices*, vol. xiii., Jan. 1853, pp. 61–66 ; see also vol. xxxvi., Dec. 1875.)—W. N.

On a Method of making a Pendulum swing in an approximately Cycloidal Arc. By General M. C. Meigs, U.S.A.

I have been amusing myself by making a "Baily compensating seconds pendulum" for an old clock.

On hanging it for the first time I notice that it twists in swinging. The twist is synchronous with the vibration of the pendulum, and at the middle of the vibration, when the pendulum is vertical, its suspending spring is flat and straight. The twisted spring is shorter than the flat one, and this twisting therefore shortens the radius of curvature of the arc described by the centre of oscillation after it passes the vertical on each side.

By suitably proportioning the width and thickness of the suspending spring, this shortening of the radius might be so regulated that the arc described would be very nearly, and if the work is perfect accurately, cycloidal.

The twist may be given by making the crutch strike a round bar placed in front of the pendulum rod, and not in the plane of vibration: the further this bar which receives the impulse is from the plane of the pendulum, the greater the twist.

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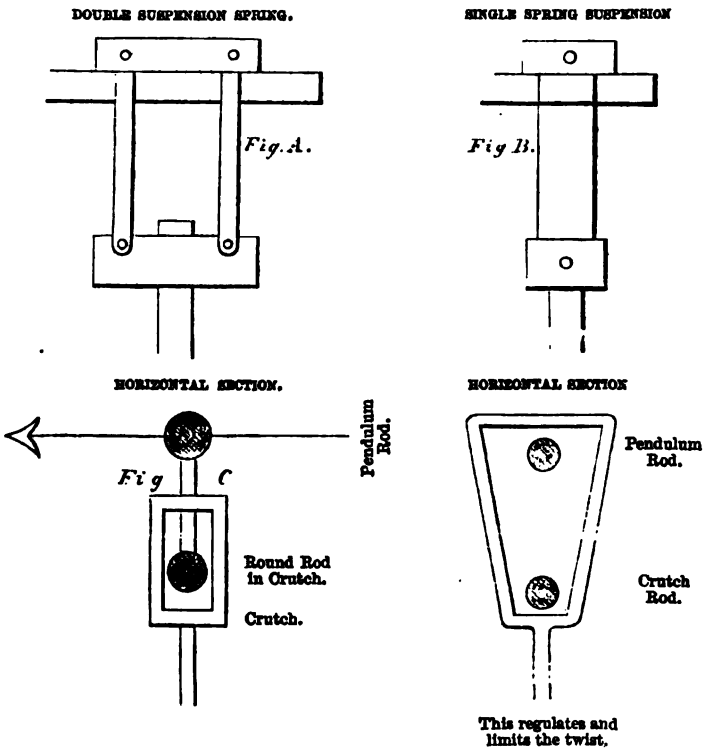
There are, then, two means of regulating the curvature of the arc, viz.:—

1. Width and length of suspension spring, or, when two parallel springs are used, the distance between them.

2. Distance from the bar which receives the impulse, to the plane of the pendulum.

I have never seen these arrangements noted in any publication on the pendulum, and if not heretofore tried, I think it might be well to try them. Huygens' cycloidal cheeks failed to secure superior accuracy.

The ordinary suspension spring probably causes the pendulum to swing in an approximately cycloidal arc, yet it is not generally exact. I think this twisting motion can be made to produce an absolutely isochronous motion through the greatest ordinary or necessary range of change in the arc of vibration of the pendulum of the astronomical clock.



These sketches illustrate constructions suggested. There is a wide range in the disposition of A, B, and C.

Quartermaster-General's Office,
Washington, April 12, 1877.

H H

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On the Opposition of the Minor Planet Melpomene as a means of determining the Solar Parallax. By Mr. David Gill.

The accompanying list contains the Stars of Comparison to be observed with *Melpomene*. The same remarks apply to them as to the case of *Mars* and *Ariadne*, for which the comparison stars were published in the last number of the *Monthly Notices*.

In the case of *Melpomene* the necessity for Meridian observations of the comparison stars is specially urgent, because from lack of suitable stars a very rigid system of heliometer triangulation cannot be arranged.

I am indebted to Dr. Auwers of Berlin for the daily places of the planet, by which I have been enabled to select the stars of comparison.

I had also intended to observe the planet *Iris*, but this could not be done advantageously without taking up a new station in about 20° N. latitude. The circumstances of the opposition of *Melpomene* are so little less favourable than *Iris* that the risk and loss of time incurred appeared to more than counterbalance the advantages offered by the somewhat nearer approach of *Iris*.

The circumstances of the opposition of *Iris*, are, however, very favourable for the application of Dr. Galle's method, and it is to be hoped the opportunity will not be lost.

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Stars to be observed with Melpomene at Opposition, 1877.

Adopted Name of Star.	Approximate. 1877·0 R.A. h m s	Dec. ° ′	Mag. in Berlin Academy Star Cat. Mag.	No. in Weisse's Bessel.	Mag.	No. in Schjellerup.	Mag.	No. in Lalande.	Mag.	Remarks.
a	4 17 16	+2 45	8	iv. 326	8	...	...	8266	8½	
β	4 18 1	2 12	8	340	8	1396 1397	8·5 8			
γ	4 19 39	0 46	7–8	381	8	...	...	8348 8349	7 8	
b	4 22 26	2 6	8–9	...	...	...	...	8437	8	
δ	4 27 14	0 46	8	544	8	...	...	8601	8½	
c	4 27 18	3 11	9	...	...	...	...	...	...	617 Arg. Zones +3°
d	4 29 24	1 11	8–9	...	...	...	...	...	...	777 „ „ +1°
e	4 30 38	2 20	9	...	...	...	...	...	...	737 „ „ +2°
f	4 32 46	1 54	8–9	685	8–9					
g	4 34 33	2 17	8	727	8					
y	4 34 39	0 44	8	...	...	...	...	8824	8	
h	4 35 8	+1 40	...	...	...	1499	8·5	...	...	798 Arg. Zones +1°

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Adopted Name of Star.	Approximate. 1877·0 R.A. h m s	Dec. ° ′	Mag. in Berlin Academy Star Cat. Mag.	No. in Weisse's Bessel.	Mag.	No. in Schjellerup.	Mag.	No. in Lalande.	Mag.	Remarks.
i	4 36 33	+2 11	8–9	774	8–9	...	...	8883	8½	
e	4 36 40	0 52	8–9	777	8–9	1512	8·7			
k	4 38 54	2 25	8–9	817	8–9					
l	4 43 9	2 0	8	902	8	...	...	9066	8	
m	4 44 26	0 56	7	936	7	...	...	9101	7	
g	4 45 51	1 38	...	...	...	1564	8·3	...	...	837 Arg. Zones + 1°
n	4 49 46	2 59	8	1067	8	1581	8·5	9268	7	
o	4 49 48	1 51	8	...	...	...	...	9270	8	
r	4 53 39	3 6	8–9	...	...	...	...	9400		
s	4 56 3	1 52	8–9	1223	8–9					
t	4 58 35	+2 29	8–9	...	...	...	...	9561	8½	

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Plan of Heliometric Triangulation of Stars to be compared with Melpomene.

Stars.	Mag.	A.R. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Dist. ′
a—*β*	8—8	4 17 38	+2 29	341	35
a—*b*	8—8-9	19 51	2 26	297	87
β—*b*	8—8-9	20 14	2 9	275	66
β—*γ*	8—7-8	18 50	1 29	344	89
γ—*b*	7-8—8-9	21 2	1 26	208	90
γ—*δ*	7-8—8	23 27	0 46	270	114
b—*c*	8-9—9	24 52	2 39	228	98
b—*d*	8-9—8-9	25 55	1 39	298	118
b—*δ*	8-9—8	24 50	1 26	318	108
δ—*d*	8—8-9	28 19	0 59	232	41
δ—*e*	8—9	28 56	1 33	208	107
δ—*f*	8—8-9	30 0	1 20	231	107
δ—*y*	8—8	30 57	0 45	271	111
d—*e*	8-9—9	30 1	1 46	195	71
d—*f*	8-9—8-9	31 5	1 33	230	66
d—*g*	8-9—8	31 59	1 44	230	102
d—*h*	8-9—8-9	32 16	1 26	251	91
d—*i*	8-9—8-9	32 59	1 41	241	123
d—*ε*	8-9—8-9	33 2	1 1	280	111
d—*y*	8-9—8	32 2	0 57	289	83
f—*g*	8-9—8	33 40	2 6	229	35
f—*h*	8-9—8-9	33 57	1 47	292	38
f—*i*	8-9—8-9	34 40	2 2	253	59
f—*k*	8-9—8-9	35 50	2 10	251	97
f—*ε*	8-9—8-9	34 43	1 23	317	85
f—*y*	8-9—8	33 43	1 19	338	76
g—*h*	8—8-9	34 51	1 59	346	38
g—*i*	8—8-9	35 33	2 14	281	31
g—*k*	8—8-9	36 44	2 21	263	66
g—*ε*	8—8-9	35 37	1 35	339	91
g—*y*	8—8	34 36	1 31	359	93
e—*f*	9—8-9	31 42	2 7	309	41
e—*g*	9—8	32 36	2 18	273	59
e—*h*	9—8-9	32 53	2 0	301	79
e—*i*	9—8-9	33 36	2 16	276	89
e—*y*	9—8	4 32 38	+1 32	328	113

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Stars.	Mag.	A.R. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Dist.
y—*h*	8—8-9	4 34 54	+1 12	187	56
y—*i*	8—8-9	35 36	1 28	198	92
y—*k*	8—8-9	36 47	1 35	184	119
y—*e*	8—8-9	35 39	0 48	255	31
h—*i*	8-9—8-9	35 51	1 56	215	37
h—*k*	8-9—8-9	37 1	2 3	231	72
h—*e*	8-9—8-9	35 54	1 16	334	53
i—*k*	8-9—8-9	37 44	2 18	248	38
i—*l*	8-9—8	39 51	2 6	276	100
i—*e*	8-9—8-9	36 37	1 32	359	79
e—*k*	8-9—8-9	37 47	1 39	200	99
e—*l*	8-9—8	39 55	1 26	235	119
e—*m*	8-9—7	40 33	0 54	268	117
k—*l*	8-9—8	41 2	2 12	291	68
k—*m*	8-9—7	41 40	1 41	317	122
k—*x*	8-9—8	42 23	2 2	294	114
l—*m*	8—7	43 48	1 28	343	67
l—*n*	8—8-9	46 28	2 30	239	115
l—*o*	8—8	46 29	1 56	275	100
l—*x*	8—8	44 30	1 49	299	46
m—*o*	7—8	47 7	1 24	236	98
m—*x*	7—8	45 9	1 17	207	48
x—*n*	8—8-9	47 48	2 18	216	100
x—*o*	8—8	47 50	1 45	258	61
o—*r*	8—8-9	51 44	2 29	218	95
o—*s*	8—8-9	52 56	1 52	269	94
n—*o*	8-9—8	49 47	2 25	0	68
n—*r*	8-9—8-9	51 43	3 3	263	59
n—*s*	8-9—8-9	52 55	2 26	305	116
r—*s*	8-9—8-9	54 51	2 29	334	82
r—*t*	8-9—8-9	56 7	2 48	297	83
s—*t*	8-9—8-9	4 57 19	+2 11	226	53

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Plan of Observation of Melpomene and Comparison Stars.

[P denotes the planet; other letters the stars in the preceding list.]

Date.	Star of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′
Nov. 12	P—*t*	8–9	4 57 19	+2 28	267·9	38	4 57 11	+2 27	266·2	42
	P—*n*	8–9	52 54	2 43	108·4	99	52 47	2 42	109·9	96
	P—*o*	8	52 56	2 9	68·7	101	52 48	2 8	68·6	97
13	P—*t*	8–9	56 55	2 26	263·3	50	56 48	2 25	262·3	54
	P—*n*	8–9	52 31	2 41	113·5	90	52 24	2 40	115·3	87
	P—*o*	8	52 32	2 7	68·6	88	52 25	2 6	68·5	84
14	P—*t*	8–9	56 31	2 24	260·7	63	56 24	2 23	260·1	66
	P—*n*	8–9	52 7	2 39	119·6	81	52 0	2 38	121·8	79
	P—*o*	8	52 8	2 5	68·3	75	52 0	2 4	68·1	71
15	P—*t*	8–9	56 7	2 22	259·3	76	55 59	2 21	258·9	79
	P—*r*	8–9	53 39	2 40	180·3	51	53 31	2 39	183·8	53
	P—*o*	8	51 43	2 3	67·4	62	51 36	2 2	67·1	58
16	P—*t*	8–9	55 41	2 20	258·5	89	55 32	2 19	258·4	93
	P—*r*	8–9	53 13	2 39	193·4	56	53 4	2 38	197·2	59
	P—*o*	8	51 18	2 1	65·6	49	51 9	2 0	64·6	45
17	P—*s*	8	4 48 53	+1 53	71·9	96	4 48 44	+1 52	71·6	91

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Date.	Star of Comparison	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ″	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ″
Nov. 17	P—*r*	8–9	4 52 47	+2 37	204·1	64	4 52 38	+2 36	207·3	67
	P—*s*	8–9	53 59	2 0	284·3	64	53 50	1 59	282 6	68
18	P—*x*	8	48 26	1 51	71·1	82	48 17	1 51	70·7	77
	P—*r*	8–9	52 20	2 36	212·8	73	52 11	2 36	215.2	76
	P—*s*	8–9	53 32	1 58	279·5	77	53 23	1 58	278·3	81
19	P—*l*	8	46 37	2 1	89·1	104	46 28	2 1	89·6	99
	P—*s*	8–9	53 4	1 57	276·1	90	52 55	1 57	275·3	94
	P—*o*	8	49 57	1 56	22·1	11	49 48	1 56	358·2	10
20	P—*l*	8	46 9	2 0	90·7	90	46 0	1 59	91·2	85
	P—*s*	8–9	52 36	1 55	273·8	104	52 26	1 54	273·8	108
	P—*o*	8	49 28	1 55	308·9	13	49 19	1 54	296·4	16
21	P—*l*	8	45 41	1 58	92·6	76	45 31	1 58	93·3	71
	P—*n*	8–9	48 59	2 28	200·6	67	48 50	2 28	204·2	69
	P—*o*	8	49 0	1 54	283·1	25	48 50	1 54	279·7	29
22	P—*l*	8	45 12	1 57	95·1	62	45 2	1 57	96·2	57
	P—*n*	8–9	48 30	2 27	210·5	75	48 20	2 27	213·5	78
	P—*o*	8	48 31	1 53	275·2	39	48 21	1 53	273·8	44
23	P—*x*	8	46 3	1 45	22·0	16	45 53	1 45	4·0	14
	P—*l*	8	4 44 42	+1 56	98·9	47	4 44 32	+1 56	100·5	42

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	P—*o*	8	4	48	1	+1	52	271·8	53	4	47	52	+1	52	271·3	58
24	P—*l*	8		44	12	1	56	105·6	33		44	3	1	56	109·0	28
	P—*m*	7		44	51	1	24	12·8	57		44	41	1	24	7·8	55
	P—*o*	8		47	32	1	51	270·1	68		47	22	1	51	269·9	73
25	P—*k*	8–9		41	35	2	7	113·6	88		41	25	2	7	115·1	83
	P—*m*	7		44	21	1	23	357·4	54		44	11	1	23	352·0	54
	P—*o*	8		47	2	1	52	269·2	83		46	52	1	52	269·1	88
26	P—*k*	8–9		41	5	2	7	118·8	75		40	55	2	7	120·9	70
	P—*m*	7		43	51	1	23	341·7	56		43	41	1	23	336·9	57
	P—*o*	8		46	32	1	53	268·8	98		46	22	1	53	268·8	103
27	P—*k*	8–9		40	35	2	7	126·0	62		40	25	2	7	129·0	58
	P—*l*	8		42	42	1	54	229·3	18		42	32	1	54	237·7	22
	P—*m*	7		43	20	1	22	328·0	62		43	10	1	22	324·1	65
28	P—*k*	8–9		38	11	1	44	84·9	92		38	1	1	44	84·6	87
	P—*l*	8		42	12	1	54	247·6	31		42	1	1	54	250·6	36
	P—*m*	7		42	50	1	22	317·4	71		42	40	1	22	314·5	74
29	P—*k*	8–9		37	41	1	44	84·0	77		37	31	1	44	83·5	72
	P—*k*	8–9		39	34	2	7	151·9	42		39	24	2	7	157·8	40
	P—*l*	8		41	41	1	54	254·8	46		41	31	1	54	256·4	50
30	P—*m*	7		41	49	1	22	303·7	94		41	38	1	22	302·2	98
	P—*l*	8		41	11	1	54	258·8	60		41	1	1	54	259·8	65
	P—*g*	8	4	36	53	+2	2	112·4	75	4	36	43	+2	2	113·7	71

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Date.	Star of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′
Dec. 1	P—*l*	8	4 40 40	+1 54	261·6	75	4 40 30	+1 54	262·3	80
	P—*f*	8–9	35 28	1 52	93·5	81	35 19	1 52	93·6	77
	P—*k*	8–9	38 32	2 7	196·7	38	38 23	2 7	203·4	39
2	P—*l*	8	40 10	1 55	263·6	90	40 0	1 55	264·1	95
	P—*f*	8–9	34 59	1 52	93·6	66	34 49	1 52	93·6	61
	P—*k*	8–9	38 2	2 7	216·3	44	37 52	2 7	221·5	46
3	P—*l*	8	39 39	1 56	265·2	105	39 29	1 56	265·6	110
	P—*f*	8–9	34 28	1 52	93·3	51	34 18	1 52	93·1	46
	P—*i*	8–9	36 22	2 0	196·3	21	36 11	2 0	209·0	22
4	P—*d*	8–9	31 12	1 33	70·7	126	31 2	1 33	69·7	122
	P—*f*	8–9	33 58	1 53	92·1	36	33 48	1 53	91·5	31
	P—*k*	8–9	37 2	2 9	240·0	65	36 52	2 9	242·5	69
5	P—*d*	8–9	30 43	1 32	67·4	113	30 33	1 32	66·1	109
	P—*f*	8–9	33 28	1 54	88·7	21	33 19	1 54	86·1	16
	P—*k*	8–9	36 32	2 10	246·7	77	36 22	2 10	248·5	81
6	P—*e*	9	31 55	2 8	121·2	45	31 45	2 8	124·0	40
	P—*f*	8–9	32 59	1 55	67·4	7	32 49	1 55	51·5	4
	P—*i*	8–9	34 53	2 4	254·1	52	34 43	2 5	256·2	57
7	P—*e*	9	4 31 26	+2 10	130·9	32	4 31 16	+2 11	136·5	28

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	P—*f*	8-9	4	32	30	+1	56	303·0	10	4	32	20	+1	57	294·8	14
	P—*i*	8-9		34	23	2	6	259·7	66		34	13	2	7	261·1	71
8	P—*e*	9		30	57	2	11	152·3	20		30	48	2	12	164·3	18
	P—*f*	8-9		32	1	1	57	289·4	24		31	51	1	58	298·1	29
	P—*d*	8-9		29	15	1	36	49·9	79		29	6	1	37	47·1	76
9	P—*c*	9		28	49	2	38	145·4	80		28	40	2	39	147·9	77
	P—*g*	8		32	27	2	11	259·3	64		32	17	2	12	260·8	69
	P—*d*	8-9		28	47	1	38	40·7	71		28	38	1	39	37·2	69
10	P—*b*	8-9		25	55	2	7	88·7	104		25	46	2	8	88·0	100
	P—*g*	8		31	59	2	12	263·7	78		31	50	2	13	264·8	82
	P—*d*	8-9		28	19	1	40	29·5	66		28	10	1	41	25·6	65
11	P—*b*	8-9		25	28	2	9	86·2	91		25	19	2	10	85·2	87
	P—*g*	8		31	31	2	14	266·9	91		31	23	2	15	267·7	95
	P—*d*	8-9		27	52	1	41	17·3	64		27	43	1	42	13·1	64
12	P—*b*	8-9		25	1	2	11	82·6	78		24	53	2	12	81·2	74
	P—*g*	8		31	5	2	16	269·5	104		30	56	2	17	270·2	108
	P—*d*	8-9		27	25	1	44	4·8	65		27	16	1	45	1·1	66
13	P—*b*	8-9		24	35	2	13	77·6	66		24	26	2	14	75·5	62
	P—*c*	9		27	1	2	45	189·5	52		26	53	2	46	194·5	51
	P—*e*	9		28	41	2	20	270·2	58		28	33	2	21	270·4	63
14	P—*b*	8-9		24	10	2	15	70·1	55		24	2	2	16	67·2	52
	P—*c*	9	4	26	36	+2	48	204·7	51	4	26	27	+2	49	209·4	52

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Date.	Star of Comparison.	Mag.	Hour Angle -4^h (Evening Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ° ′	Position Angle. °	Distance. ′	Hour Angle $+4^h$ (Morning Observations). R.A. of Middle Point. h m s	Dec. of Middle Point. ′ °	Position Angle. °	Distance. ′
	P—*e*	9	4 28 16	+2 22	273·8	71	4 28 7	+2 23	274·6	75
Dec. 15	P—*β*	8	21 33	2 21	80·7	107	21 25	2 22	79·5	104
	P—*c*	9	26 11	2 50	218·8	53	26 4	2 51	223·2	55
	P—*e*	9	27 51	2 25	276·4	84	27 44	2 26	277·2	88
16	P—*β*	8	21 9	2 23	76·6	96	21 1	2 24	75·1	93
	P—*c*	9	25 47	2 52	231·2	58	25 39	2 53	234·6	60
	P—*e*	9	27 27	2 27	278·6	96	27 20	2 28	279·2	100
17	P—*a*	8	20 23	2 42	93·3	94	20 16	2 43	92.3	90
	P—*b*	8–9	22 58	2 23	25·4	37	22 51	2 24	19·2	37
	P—*c*	9	25 24	2 55	241·2	65	25 17	2 56	244·0	68
18	P—*a*	8	20 1	2 45	89·9	82	19 54	2 46	88·5	79
	P—*b*	8–9	22 36	2 26	7·3	40	22 29	2 27	2·1	40
	P—*c*	9	4 25 2	+2 58	249·2	73	4 24 55	+2 59	251·5	75

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The Approaching Opposition of Mars. By R. A. Proctor, Esq.

Want of leisure has prevented me from preparing, as I had intended, a paper indicating the probable appearance of *Mars*, on different days, during his approaching opposition. Herr Marth's excellent Ephemeris in the last number of the *Notices* in large degree subserves the purpose of anticipatory charts, such as I drew in March 1873; for it is easy from the data he supplies to make orthogonal projections for any given day and hour.

My chief object in writing now, however, is to express my agreement with Dr. Terby, of Louvain, as to the doubtful features of my chart. Indeed several of the doubts he suggests had been indicated by the use of dotted outlines in my map. I agree with him also in considering that M. Flammarion's course, in *making* all the corrections which Dr. Terby says rightly may *have* to be made, is too summary. In some respects, indeed, the corrected chart is certainly incorrect. Thus, it carries Nasmyth Inlet eastwards as a narrow strait to join Tycho Sea, which may or may not be right; but a correction which will certainly have to be made in this part of the map is overlooked altogether. I refer to a bay running southwards from this strait into Dawes Continent. This is shown well in drawings by De la Rue, Knobel, and Green. I find it is shown in several of the views given me by Dawes, though not in the best. I ought to have remembered that positive evidence for a dark marking is altogether stronger than negative evidence against it. For a similar reason, on the other hand, I think it unlikely that the J. Herschel Strait of my chart does not extend into De la Rue Ocean. For some of Dawes's best drawings, in making which he paid special attention to this region, show the strait continuous. See especially his drawing numbered 10 in vol. xxv. of our *Notices*. See also Mr. Knobel's excellent series of drawings in vol. xxxiii. This positive evidence seems conclusive. The marked gap in Lockyer's views (among the best we have) indicates that clouds had gathered over that region—where the strait is manifestly shallow, so that mid-day clouds would readily form, as over shallow seas on our own Earth.

I have here used my own nomenclature, which was devised simply for convenience of reference. If Dr. Terby had altered the names, all or any, I should have adopted the names he used. But as he, who has given so much attention to the subject and studied so many drawings, has adopted my nomenclature, I have not thought it necessary to follow M. Flammarion (who employs Dr. Terby's results and my own) in changing most of the names. The changes seem uncalled for and likely to introduce confusion.

2 *North Road, Clapham Park, S.W.*

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Note on the Coming Opposition of Mars. By N. E. Green, Esq.

In order to utilise the Opposition of this interesting planet, and secure a fair amount of uniformity in the drawings of various observers, special forms have been printed on a paper possessing peculiar facilities for the production of effect.

This paper consists of an under-surface of white enamel covered with a warm tone closely resembling the general tint of *Mars*. Upon this surface the dark marks may be drawn either with chalk or pencil, and softened with the stump in the usual manner.

The peculiar advantage consists in the use of the knife, by which the most delicate alterations of tint or form may be effected, or the warm tone partially removed for faint lights, or entirely erased for the polar snows.

The only care required is to avoid the use of india-rubber, all general softening or removal being effected by bread.

Sheets of these forms may be obtained at the monthly meeting in June, or by letter to N. E. Green, 3 Circus Road, St. John's Wood, who will feel much pleasure in supplying them to the Fellows.

Note on the Distribution of the Fixed Stars.
By R. A. Proctor, Esq.

Von Littrow has shown that when only the numerical relations of stars of various orders of brightness are considered, the increase in the number of the fainter stars corresponds with the theory that apparent magnitude depends chiefly on distance. When, however, the localisation of stars of various orders is considered, we find evidence of the numerical superabundance of stars really smaller than their neighbours. To take a rough illustration of the effect of this consideration: If, in examining any telescopic field taken at random, we find for each increase of illuminating power an increasing number of stars, the inference is that we are penetrating further and further into space. But this inference must be rejected if we find that the field of view lies in either of the *nubeculæ*, and that the increase is not recognised, or only occurs in a markedly less degree, outside the borders of the star-cloud. In like manner, though not so obviously to ordinary vision, we find evidence of the existence of clouds of stars or streams of stars (such as are found in various parts of the Milky Way); and numerical increase with increasing powers, if found within such clouds and in markedly less degree outside their borders, cannot be referred to increase of distance, but, according to the laws of probability, must be explained as due to the recognition of stars really smaller lying within the limits

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of such clouds or streams. (By streams I do not mean rows of stars, but stream-shaped *regions* in which are many thousands of stars.) I think my Chart of 324,000 Stars in the Northern Hemisphere demonstrates this, especially when it is remembered that the regions where *these* stars (largely exceeding in number those dealt with statistically by Von Littrow, or indeed, so far as I know, by any other) chiefly congregate, are precisely the regions where stars down to the 20th magnitude are found in greatest number. As Mr. W. M. Christie remarks in a very able and impartial review of my researches (*Academy* for June 27, 1874), "it is hardly conceivable that" the clustering aggregations "should be enormously long cylinders or spindles, turned in every case exactly towards us."

It appears to me that direct evidence based on the laws of local aggregation, as deduced from isographic charting (which is in effect statistical enumeration recorded so that all its classifications can be *seen*), cannot be disposed of by a less perfect method of counting, in which averages only are considered without reference to localisation. This would be much as though an archæologist's theory respecting certain mounds in a plain should be met by a surveyor with the argument that the mounds had no real existence, seeing that, if they were levelled, the plain would not rise appreciably, where they had been, above the surrounding level. If the mounds could be thus disposed of, any theory respecting them would fall to the ground. In like manner, I must admit that if no attention be paid to the evidence of stellar aggregation in particular regions of the heavens, there remains little evidence of the existence of real stellar aggregations in space.

Visible Transits of Mercury to the Year 2000.

By Rev. S. J. Johnson.

Upon recently making an examination, for curiosity, of the transits of *Mercury* that were to be expected in this land till the close of the next century, I found the method of cycles, even that of 263 years, would not answer in many instances, as, owing to the difference of the planet's geocentric latitude at the return of the period, the duration of the transit may vary considerably. I therefore computed the places of ☉ and ☿ from some approximate tables—those given in Lindsay's *Chrono-Astrolabe*—and the results will, I believe, deviate little from the truth.

Thirteen transits of *Mercury* fall in the present century, but one only, that of 1832, was visible throughout at Greenwich. In the next century twelve happen, four of them being entirely visible there.

After the transit of 1878 there will be no opportunity for a good observation of this sort in the remaining years of this

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century, as in 1891 the planet leaves the Sun scarcely half an hour after sunrise, and in 1894 the ingress is but a quarter of an hour before sunset.

Sometimes a period of thirty years elapses that is transitless so far as we are concerned in this country, as between the years 1802 and 1832, and from 1973 to 2003.

(Contacts below the horizon are omitted.)

1881	Nov. 7	Below the horizon.					
1891	May 10	„	„		Egress about	$4\frac{3}{4}^h$	morn.
1894	Nov. 10	Ingress about	4^h	aft.			
1907	Nov. 12	„	„	$10\frac{1}{4}^h$ morn.	„	„	$1\frac{1}{4}^h$ aft.
1914	Nov. 6	„	„	$9\frac{1}{4}^h$ morn.	„	„	2^h aft.
1924	May 7				„	„	$5\frac{1}{2}^h$ morn.
1927	Nov. 8				„	„	$8\frac{1}{4}^h$ morn.
1937	May 10	„	„	8^h morn.	„	„	$9\frac{1}{4}^h$ morn.
1940	Nov. 10	Below the horizon.					
1953	Nov. 13	Ingress about	$3\frac{1}{4}^h$	aft.			
1960	Nov. 6	„	„	$2\frac{1}{4}^h$ aft.			
1970	May 9				„	„	noon.
1973	Nov. 9	„	„	$7\frac{3}{4}^h$ morn.	„	„	1^h aft.
1986	Nov. 12	Below horizon.					
1999	Nov. 14	Below horizon.					

Upton Helions Rectory,
Crediton.

Extract from a Letter received by Mr. Ranyard from Prof. Meucci of the Museo Reale, Florence.

I have recently found, in the collection of instruments under my care, an Arabian Celestial Globe, which I believe is certainly the oldest of the few in existence; its date is 1081 A.D. It is made of metal, and its diameter is 209 millimeters. It represents the celestial sphere as given by Ptolemy, except that the longitudes of all the stars are augmented by 14° 10′, so that we find *Regulus* at 16° 40′ ♌ &c. The names of the constellations are all in cufic characters. There is also an inscription in the same character to the effect that the globe was made by Ibrâhîm Ibn Saîd al Sahlî al Wazzon (the Weigher), with his son Muhammed. The work, it appears, was finished in Valencia, in the beginning of the month Safar, in the year of the Hegira 474 (this month began July 11, A.D. 1081), and it was made for Abu Isa Ibn Labbun (or Lebûn).

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. JUNE 8, 1877. No. 8.

WILLIAM HUGGINS, ESQ., F.R.S., President, in the Chair.

Major-General John Baillie, 25 Hamilton Terrace, St. John's Wood;
Thomas Brewin, Esq., 14 St. Nicholas Street, Leicester;
G. Calver, Esq., Hill House, Widford, Chelmsford;
James Campbell, Esq., F.R.G.S., Arkley House, Barnet; and
W. F. Denning, Esq., Tyndale House, Ashley Down, Bristol;

were balloted for and duly elected Fellows of the Society.

The Rev. T. Tordiffe and Mr. J. Garbutt were expelled from the Society for non-payment of arrears of subscriptions.

Note on some of M. Stephan's *New Nebulæ.*

By J. L. E. Dreyer, Esq.

Among the new Nebulæ, the positions of which were given by M. Stephan in the April No. of the *Monthly Notices*, are a few which already have been found before. M. Stephan has himself suspected this in the case of No. 12 of the first list, as he says: "Le No. 12 est peut-être identique avec 440 Lassell." This identity is, however, quite certain, as the Nebula in question has been found independently by D'Arrest, whose position, brought up to 1876, is

$21^h\ 20^m\ .9^s.3 \qquad 97°\ 32'\ 13''$

in perfect accordance with M. Stephan.

With respect to Nos. 1 and 2 of the second list, a comparison with D'Arrest's observations will likewise show that these are identical with H. III. 441 and 442. D'Arrest (who has found near this place several new Nebulæ which seem to have escaped M. Stephan) has the following positions for 1860:—

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h	m	s	°	′	″
1	20	18·9	92	38	49
1	20	37·9	92	36	55

while the places of M. Stephan are for 1860 :—

h	m	s	°	′	″
1	20	18·8	92	38	17
1	20	40·8	92	36	15

The "General Catalogue" is therefore wrong with respect to these two Nebulæ, while Auwers finds positions which agree better with the modern determinations.

Through the kindness of M. Stephan I have been able to insert these two lists of Nebulæ in my supplement to the "General Catalogue," which was read before the Royal Irish Academy in February last, and which I hope will soon be in the hands of astronomers. The numerous cases in which Marseilles nebulæ had been discovered independently by D'Arrest or Marth, have shown that M. Stephan almost always estimates the nebulæ far fainter than the other observers of nebulæ. The descriptions "eeF," "presque inobservable," &c. should therefore not deter observers from looking for these objects.

Earl of Rosse's Observatory,
June 1877.

Note on the new Inequalities in the Moon's Longitude, pointed out by Mr. Neison. By S. Newcomb.

The inequalities in the Moon's longitude pointed out by Mr. Neison in the April No. of the *Monthly Notices*, if real, are so important, that I may be permitted to express the desire to see his computations of them published *in extenso*. They are, properly speaking, inequalities of long period in the mean longitude and in the eccentricity and perigee of the Moon, produced by the action of *Jupiter*, admitting of being expressed as follows :—

$$\delta l = +2''.20 \sin (2\varpi - 2J),$$
$$e\delta\varpi = +0''.58 \sin (2\varpi - 2J),$$
$$\delta e = -0''.58 \cos (2\varpi - 2J),$$

ϖ being the longitude of the Moon's perigee, and J the mean longitude of *Jupiter*. The value of the varying angle is

$$2\varpi - 2J = 287°.0 + 20°.65\,(t - 1800.0),$$
$$= 239°.4 + 20°.65\,(t - 1850.0).$$

My present object is to show how strongly the reality of these inequalities is indicated by observations. In No. 3 of Papers

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published by the Transit of *Venus* Commission, pages 20–29, I discussed an apparent inequality in the eccentricity and perigee of the Moon, having a period of about $16\frac{2}{3}$ years; an abstract of which discussion is given in the *Monthly Notices* for June, 1876. The notation used was

$$h' = -2\,\delta e,$$
$$k' = \quad 2e\delta\varpi;$$

substituting δe and $e\,\delta\varpi$ for h' and k', the inequality indicated was

$$\delta e = 0''.75 \sin N,$$
$$e\delta\varpi = 0''.75 \cos N,$$

in which the value of N indicated by observations was

$$N = 163°.2 + 21°.6\,(t - 1868.5);$$

and therefore, putting

$$N' = N + 90° = 253°.2 + 21°.6\,(t - 1868.1),$$

the inequalities were equal to

$$e\delta\varpi = -0''.75 \sin N',$$
$$\delta e = \quad 0''.75 \cos N'.$$

We have, then, for the comparison of the angle N′ derived empirically from observations, and the angle $2\varpi - 2J$ of theory

$$N' = 253^{\circ}.2 + 21^{\circ}.6 \quad (t - 1868.1),$$
$$2\varpi - 2J = 261.4 + 20.65\,(t - 1868.1).$$

The correspondence is so close that the identity of the two arguments does not seem to admit of reasonable doubt.

What is worthy of remark is, that the period of this argument differs but little from that of the Moon's node, so that the inequalities in question may, for many years at a time, appear to depend on the position of the Moon's node. They will therefore produce apparent inequalities like those containing the Moon's mean anomaly, and the longitude of its node, which have been deduced by the Astronomer Royal in the *Memoirs of the Royal Astronomical Society*, vol. xxix., pp. 13–15.

The inequality of mean longitude will account for the difference between the values of the inequality depending on the ellipticity of the Earth as found from theory and from observations. Hansen's theoretical value is

$$7''.76 \sin\{151° + 19°.34\,(t - 1800)\},$$

while the Astronomer Royal found a co-efficient of 6″.44. Now, in 1800, the argument of Mr. Neison's inequality was 136° greater than that of Hansen. The excess increased from 71° in 1750

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to 201° in 1850. The effect of the new inequality was, it will be seen, to diminish the apparent inequality due to the ellipticity of the Earth during the period 1770–1850, the diminution being zero at the first epoch, and attaining its maximum of 2″·2 between 1840 and 1850.

A more definite statement of the support which the observations give to the inequality of longitude cannot be expressed without a more continuous comparison of Hansen's tables with observations than now exists.

On the Spectra of Comets b and c, 1877. By Lord Lindsay.

Already, on April 11, the spectrum of Winnecke's Comet, (*b* 1877) was seen to consist of three bright lines. Under a very low dispersive power these seemed to be connected by the very narrow continuous spectrum of the nucleus; but on subsequently applying a higher power it was obvious that, although the lines were much widened when the image of the nucleus fell on the slit, still the spectrum was broken up into three lines separated by wide dark intervals.

Measures were obtained with a Browning single prism spectroscope, on April 18, by Copeland and G. Lohse: the resulting wave-lengths in millionths of a millimeter are

556·0 Very faint line.

516·0 Bright line abruptly terminated on the side next the red, but gradually fading away towards the violet.

472·2 Faint line, somewhat sharply bounded towards the red.

On May 5 the same instrument gave wave-lengths 558·0, 508·6, 467·9; the lines being much the same as before.

The following night was very clear, and by using a very low eye-piece the lines were found to be visible, even in a Grubb spectroscope with a large compound prism. The least refrangible of the three lines was now found to be separated into at least three very faint lines, *see figure*. A series of measures gave the wave-lengths as follows:—

569·6 Very faint line.

559·3 } Very faint band.
550·0 }

543·2 Very faint line.

} These form parts of one band.

517·5 }
498·6 } Limits of brightest line.

513·4 Brightest part of brightest line.

510·7 Centre of light of brightest line.

470·5 Brightest part of faintest line.

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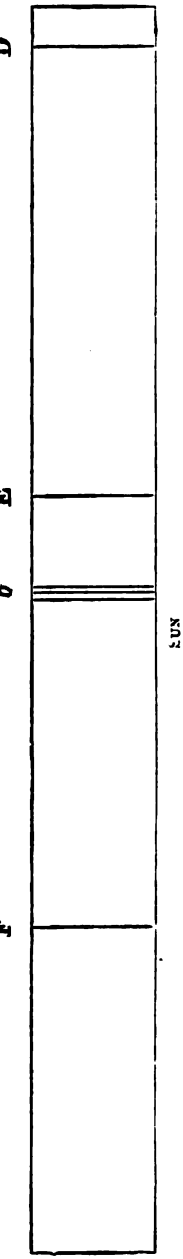
Comet b (Winnecke), 1877, May 6.

Comet c (Borelli), 1877, May 6.



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The spectrum of this comet much resembles that of Comet II. 1868, as figured by Dr. Huggins in the *Phil. Trans.*

The spectrum of Comet c was first successfully measured on May 5: it too consisted of three bright lines, but none of them coincide with those of the other comet. The results are

m.m.m.	
467·6	Faintest line; brightness = 2.
507·9	Brightest line; „ = 5.
528·2	„ „ „ = 3.

The last line is very close to E of the Solar Spectrum. There we have to deal with a comet closely allied to Brorsen's Comet of 1868 and Comet I. 1871.

The measures were all made with a spider's line, or a steel cone, in either case feebly illuminated in an otherwise perfectly dark field. The steel cone is probably the best, as it gives a broader line and requires less illumination.

Dunecht Observatory,
1877, *May* 8.

On two "Flats" on the Moon's Limb, observed March 23, 1877.

By Dr. Ralph Copeland.

(*Communicated by Lord Lindsay.*)

At $11^h\ 50^m$ G.M.T. on March 23, 1877, while preparing to observe the reappearance of *κ Geminorum*, I noticed two remarkable "flats" on the Moon's limb. The position angles of their centres were found to be 264° 28′ and 272° 30′; their lengths being 1′ 39″·1 and 1′ 18″·2 respectively. These depressions coincided sensibly with a spider's line throughout their entire length. Assuming the lowest points to have been exactly on the Moon's limb, the above measures give the following results:—

Depressions of March 23, 1877.

	1st Depression.	2nd Depression.
Length in arc of Moon's limb	5° 46′	4° 31′
Apparent depth	1″·24	0″·78
„ „ in toises	1125	703
Selenocentric Latitude	−14° 25′	− 6° 1′
„ Longitude	+87 18	+86 41

For the sake of comparison, it may be mentioned that the height of *Pico* is 1,062 toises according to Beer and Mädler.

It is highly probable that these indentations are identical with two of those seen by the Rev. H. Cooper Key on September 6, 1863. The second of them was again seen by Mr. Birt on November 3 and 4, 1864, and still later on November 12, 1875.

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But the best observations I have been able to find are by Dr. Erck on November 11, 1875, who observed them with his 7½-inch Alvan Clarke (See *Astronomical Register*, No. 156). His words are: "On laying the thick bars of the micrometer parallel to them I found their position, inverted, to be respectively 153° and 146°. The largest of the two flats was at 153°, and for something more than 3 minutes of arc, corresponding to 12° of lunar latitude, the limb did not deviate from the straight edge of the bar." It is not quite clear what is meant by "inverted" positions, but supposing them to be counted from the parallel—they were measured with the bars—the positions would become 243° and 236°, and would fall on the Moon's bright limb,* and the depressions would be identical with those observed at Dunecht, the results being:—

Depressions of November 11, 1875.

	146° Depression.	153° Depression.
Length in arc of Moon's limb		10° 18′
Apparent depth		4″·05
,, ,, in toises		3599
Selenocentric Latitude	−14° 21′	− 7° 20′
,, Longitude	+85 3	+84 16

The depth is nearly equal to that of *Newton*, the deepest known crater in the Moon, the bottom of which is 3727 toises below the highest peak of the rim.

Guided by the above results, there is no difficulty in coming to the conclusions that—

The 1st of the depressions is most probably caused by the presence of the adjoining ring-plains *Ansgarius* and *Behaim* on the Moon's limb;

And that the 2nd depression is undoubtedly a vertical section of *Kästner*.

Schroeter, who first described the ring-plain *Kaestner*, saw it on the terminator 20 hours after full moon on February 23, 1796. The grey surface of the plain then appeared to be entirely cut off from the Moon by the shadows of the mountains on the eastern margin. On the occasion of its discovery (September 30, 1792) Schroeter found the length from N. to S. to be 3′40″, a measure fairly agreeing with Dr. Erck's "something more than 3 minutes of arc." Beer and Mädler have also seen the floor of *Kästner* separated from the rest of the Moon, but the Rev. Cooper Key seems to have been the first to notice its projection on the Moon's limb.

Dunecht, June 7, 1877.

* 153° and 146° are out of the question, as being on the dark limb; but, fortunately, Mr. Birt's general account of the appearance and position of the depressions on the following evening points positively to a part of the limb near *Kästner*.

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Occultations observed at Windsor, N. S. Wales, in the year 1876, with the 4½-inch Equatoreal. By J. Tebbutt, Esq.

Date of Obs. 1876	Star.	Disapp. or Reapp.	Observatory Mean Time. h	m	s	Estimated angle from Moon's N. Cusp. °	Remarks.
June 2	Spica	D	12	34	7·2	80 E.	Disappearance instantaneous. Obs. a small fraction of a second late.
2	„	R	13	39	5·2	80 W.	Obs. not so good as that of the disappearance.
July 3	Antares	D	12	14	41·0	50 E.	About one-tenth of a second late.
3	„	R	13	7	32·9	45 W.	Good observation.
Aug. 26	Star, 8 mag.	D	7	58	11·7	80 E.	Disappearance instantaneous.
26	Star, 8½ mag.	D	8	46	54·6	45 E.	Star extremely faint, and observation uncertain to a second or two.
26	Star, 8 mag.	D	8	53	6·1	45 E.	Star faint.
26	Star, 7 mag.	D	9	1	44·0	50 E.	Very good observation.
26	Star, 4½ mag.	D	9	45	1·4	120 E.	Disappearance instantaneous.
26	Star, 8 mag.	D	9	49	51·7	100 E.	Star rather faint.
26	Star, 5½ mag.	D	10	10	10·0	100 E.	Disappearance instantaneous.
Oct. 28	λ Aquarii	D	7	50	21·6	45 E.	The instant of disappearance was lost owing to momentary removal of eye from telescope. The disappearance could not have taken place more than two seconds previously to the recorded time.
28	„	R	9	12	51·4		A small fraction of a second late.
28	78 Aquarii	D	9	30	39·7	45 E.	Disappearance instantaneous.

P.S.—*Vulcan* was searched for by me at short intervals on the 22nd and 23rd ult., and occasionally on the 24th, but without success.

Windsor, April 5, 1877.

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Observations of α Centauri. By R. L. J. Ellery, Esq., F.R.S.

As I see in the *Monthly Notices* that Mr. Marth has urged observations of *α Centauri* at the present time, I subjoin the results of our observations of this Binary.

From measures obtained in March and April 1877, the distance of the components appears to be 3″·3 and the position 69°·1. In 1862 the position was 0°·0, and distance 10″, since which time the position angle appears to have gradually increased, the distances obtained ranging from 10″ in 1862 down to 8″ in 1874, with an indication of a maximum about 1868.

The close proximity of the components at present, combined with their great brightness, render accurate measure of position a very difficult matter, and also, no doubt, interferes with very precise distance measures. Further measures shall be made, and the results forwarded to the Society.

The following are the only measures recorded at this Observatory :—

	Dist. ″	Pos. °
1863·75	8·5	5·2
1864·72	8·1	...
1868·17	9·2	...
1868·18	9·6	...
1870·65	10·2	...
1873·16	8·3	...
1874·15	8·0	30·5
1876·61	4·5	50·1
1876·62	3·8	52·0
1876·94	4·5	51·2
1877·19	3·3	
1877·21	3·4	
1877·28	2·8	69 1
1877·28	2·98	
1877·28	3·16	

Each result is the mean of from 6 to 10 measures of distance, and from 2 to 10 of position.

The table below gives the position and distance as deduced from our Transit Circle observations of α^1 and α^2 *Centauri*, and although they can scarcely be taken as so accurate as the micrometer measures, they indicate the movement of the system with considerable precision.

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Angle of Position and Distance of α^1 *Centauri* with regard to α^2 *Centauri*, from Melbourne Transit Observations.

Year.	Dist.	P.	No. of Measures.
1862·47	...	o	3
	′	°	
1865·56	9·95	17·3	1
1868·51	11·02	21·8	5
1870·65	10·45	24·7	3
1871·51	9·41	24·2	1
1872·55	10·36	24·1	1
1875·94	6·68	39·3	1
1876·90	4·94	64·3	1

Melbourne Observatory,
1877, *April* 17.

On the Collective Light and Distribution of the Fixed Stars.

By John J. Plummer, M.A.

The object of the following paper is to determine within fair limits of approximation the total illuminating power of the stars as compared with some acknowledged photometric standard. In endeavouring to do this I have been led to certain considerations regarding the distribution of the stars in space which are not in accordance with the theory so ably enunciated by Mr. Stone in the March No. of the *Monthly Notices*, but point to a more complicated structure of the sidereal universe. Although readily obtainable from existing data, these remarks may not be the less interesting to the fellows of the Society, as I am not aware that they are to be found elsewhere.

The numbers of the stars of each magnitude are now known with great accuracy for the northern hemisphere, from the careful analysis by Littrow of Argelander's *Survey of the Northern Heavens*. Nothing more satisfactory could be desired as regards the enumeration of the stars. The photometric value of Argelander's scale of magnitudes has been investigated by Pogson. The light-ratio determined by this observer is 2·512, but it will be sufficiently approximate to assume the first decimal place only as accurate. Further, it does not seem possible to fix any inferior limit to the magnitude of the stars which contribute towards illuminating sensibly our Earth, because it is well known that those which individually are too faint to affect the retina of the eye, when congregated in sufficient numbers, become distinctly visible as hazy light; and it would appear that every star, however small or isolated, must aid in the general illumination of the heavens in proportion to its apparent lustre.

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The following table has been obtained by combining the two sources of information already mentioned, and gives the number of sixth magnitude stars to which the total light of the stars of the several classes into which Littrow has divided the *Durchmusterung* are equal:—

Class.	Limiting Magnitudes.	No. of Stars in Northern Hemisphere by Littrow and Argelander.	No. of Stars of 6th mag. to which they are equal.
1	1·0 to 1·9	10	646·6
2	2·0 „ 2·9	37	957·0
3	3·0 „ 3·9	130	1344·9
4	4·0 „ 4·9	312	1291·1
5	5·0 „ 5·9	1001	1656·9
6	6·0 „ 6·9	4386	2904·0
7	7·0 „ 7·9	13823	3660·9
8	8·0 „ 8·9	58095	6154·4
9	9·0 „ 9·5	237131	12069·3

If we assume that one-half of the light in class 6 comes from stars that are visible to the naked eye, we shall have the brighter stars equal to .7349, and the telescopic stars down to the 9·5 magnitude inclusive, equal to 23337 standard stars of the sixth magnitude, or that fully $\frac{3}{4}$ of the light of a fine night is derived from stars individually invisible to the naked eye. Next, taking the light of *Sirius* equal to 324 stars of the sixth magnitude, it will be found that the total light of the whole of the stars of the *Durchmusterung* is equal to 10·17 × *Venus* at maximum brilliancy, or to $\frac{1}{78{\cdot}6}$ of the mean full moon. As these results must be approximately true for any hemisphere of the heavens, it follows that (disregarding the light of the fainter telescopic stars, of whose numbers we have no estimate) the illuminating power of all the stars above the horizon at one time is not less than $\frac{1}{80}$th part of the illumination due to the full moon; but it should be remarked that in this estimate no deduction has been made for the absorption of light in passing through the lower portions of our atmosphere.

With reference to the stars fainter than those here considered, a difficulty presents itself. If their numbers increase in the same ratio as obtains in those for which we have determined a light equivalent, it must be admitted that only a small portion of the stellar light has been here taken into account; and it becomes desirable to determine whether from some cause or other there does not exist a greater number of stars of the 9th and 10th magnitudes than the usual theory of stellar distribution in space will account for. In dealing with large numbers of stars the most probable supposition is, that variations of real lustre will be equalised, and that an average equal distribution fairly repre-

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sents the actual condition of things. This amounts to the assumption that distance is the sole cause of variation of magnitude, which, while manifestly untrue for a few stars, must be accepted as approximately accurate for large numbers. If, therefore, we select one of the classes in Littrow's analysis as containing an average number of stars compared with the space included within the limits of distance which the light-ratio assigns, it is easy to determine the number of stars that each of the other classes should contain. I have calculated these numbers for each class, on the supposition that class 8 contains such an average density of the stellar stratum, whose limits are determined by the light-ratio previously used; but, from what has already been said, no great accordance is to be looked for except where a large number of stars are concerned.

Class.	True Numbers according to Littrow.	Calculated Numbers.'	Radius of Sphere forming Exterior Limit of Distance (Dist. of 6th Mag. Star=1).
1	10	5	0·156
2	37	15	0·247
3	130	60	0·391
4	312	238	0·618
5	1001	941	0·977
6	4386	3718	1·545
7	13823	14697	2·443
8	58095	(58095)	3·863
9	237131	99631	5·085

An inspection of this table shows that the final class contains a much larger number of stars than can be accounted for in this manner, and further that the comparison would not have been materially altered had either of the four preceding classes been selected as of average density. The significance of this fact may perhaps be more strikingly shown thus. Within the limit 0·39 the numbers of the stars exceed the average, but are too few to admit of our saying decisively that they do not conform to the law of density that prevails at greater distances. From 0·39 to 3·86 one uniform law of stellar distribution prevails, while from 3·86 to 5·08 more than twice that density of stars must be assumed to account for their greatly increased numbers. The use of the light-ratio found by Carrington is equally ineffective to explain the facts, and there appears to me but two suppositions capable of doing so. Either the *Durchmusterung* of Argelander contains many stars (more than one-third of the entire number) which, though rated as 9·5 magnitude, are sensibly below it,* or

* This is equivalent to assuming that the light-ratio, which applies well to the whole of the earlier portions of the scale, fails completely towards the end, and it is a point which I have long had some intention of investigating. At present it is but justice to the deserved reputation of Argelander to assume that his scale of magnitudes is as uniform at the end as elsewhere.

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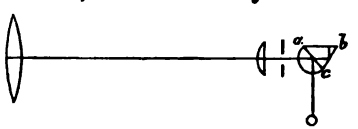
else it must be assumed that, at the average distance for stars of this magnitude, a denser stratum actually exists, succeeded possibly by regions less fruitful beyond. Having been led to the latter conclusion in opposition to preconceived ideas, I cannot but think that the enormously increased ratio with which the numbers of the telescopic stars are multiplied is deserving of increased interest and continued discussion.

Orwell Park Observatory.

A new Solar Eye-piece. By Prof. Zenger.

The Solar Eye-pieces for viewing the Sun by large telescopes were devised for the purpose of getting rid of the obnoxious glare of the solar radiation. By dark coloured glasses, absorbing fluids, reflection from polished glass surfaces, with or without the aid of polarisation of light, it was possible to view the Sun. But all these contrivances could not entirely satisfy the requirements of solar observations; either there was a much diminished field, as is the case in using Dawes's solar eye-piece, or there was a loss of definition by the use of polarising eye-pieces, or by double or triple reflection from the plane surfaces.

To obviate all these hindrances, I imagined a solar eye-piece consisting of a catadioptric lens, the last lens in the eye-piece being replaced by a hemispherical lens, with a carefully worked plane surface, inclined 45° to the optical axis of the telescope. By this replacement the field of view is scarcely affected at all, and the definition is unaltered, or even improved; for the hemispherical lens reflecting the solar rays into the eye at (O) works like a spherical lens, and the curvature may be lessened in comparison with a plano-convex lens in the ratio



$$1 : \frac{2-n}{2}, \text{ or nearly } 1 : 0{\cdot}24 = 25 : 6 = 4\tfrac{1}{6} : 1.$$

There is an equilateral prism placed in optical contact with the plane surface of the hemispherical lens, and denoting by n the index of refraction of the lens, and by n' that of the prism, the intensity of the reflected light by the plane surface ac will be

$$\frac{T_r^2}{T^2} = \frac{\tan^2(\alpha-\alpha')}{\tan^2(\alpha+\alpha')}.$$

The central rays falling on the lens and emerging after reflection, at the angle of 45°, by ac, will be greatly reduced in intensity if there is only a small difference in the reflecting power of the two media.

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We get

$$\sin \alpha' = \frac{\sin \alpha}{\frac{n'}{n}} = \frac{n}{n'\sqrt{2}};$$

if $n = 1{\cdot}53$, and $n' = 1{\cdot}544$, we have:—

$$\sin \alpha' = \frac{1{\cdot}53}{1{\cdot}544\sqrt{2}} = 0{\cdot}70695,$$

$$\alpha' = 44^\circ\ 28'\ 58''{\cdot}1,$$

$$\alpha - \alpha' = 0^\circ\ 31'\ 1''{\cdot}9;$$

$$\log \tan (\alpha - \alpha') = 7{\cdot}9555421$$

$$\log \tan (\alpha + \alpha') = 12{\cdot}0730141$$

$$5{\cdot}9125280$$

$$2 \log \frac{\tan (\alpha - \alpha')}{\tan (\alpha + \alpha')} = 1{\cdot}8250560 - 10,$$

$$\frac{\tan^2 (\alpha - \alpha')}{\tan^2 (\alpha + \alpha')} = 6{\cdot}6843 . 10^{-9}.$$

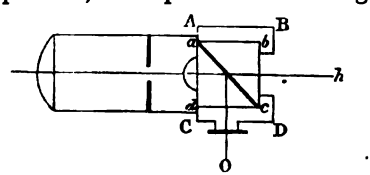
Taking the light of the full moon $= 10^{-6}$ of the solar intensity, we get

$$\frac{T_r^2}{T\mathbb{C}^2} = 6{\cdot}6843 . 10^{-3},$$

or the intensity is diminished to 0·007 of the intensity of the full moon as viewed through the telescope.

The diminution of light is sufficient to bear the whole aperture of my four-inch refractor, or of my 4½-inch Browning with reflector, not the slightest trace of heat rays being perceptible at O, in the reflected light from the plane *ac*, but the radiation at *h* is sufficient to crack the dark glass and melt it.

It is even possible to leave the eye-pieces unaltered, and to place behind the last lens, as nearly in contact with it as possible, two equilateral reflecting prisms *abb'c*, in optical contact with each other, the hypothenuses *ac* being in optical contact. Nearly the whole radiation of light and heat is conducted to *h*, only 7×10^{-9} of it being reflected to the eye at O.



A dark chamber of blackened brass plate is placed round the double prism to get rid of the dispersed light, leaving an opening near the eye.

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Both dispositions show the Sun in a most surprising manner, free from any coloration, as an intensely white ball, bluish at the middle, and rapidly decreasing in intensity, the borders being of a greyish yellow tint. A 2½-inch Plösal Dialyse shows the same colour as the 4-inch refractor, though the secondary spectrum in the former is much more visible than in the larger telescope. I suppose this colour to be due to a diminished intensity of light, together with a yellowish ruddy coloration of the borders by the absorption of light in the deeper layer of solar atmosphere through which the light passes.

Prague, March 17, 1877.

Corrections to Struve's Double Stars contained in the Dun Echt Observatory Publications, Vol. I. By Lord Lindsay.

Mr. Burnham of Chicago, U. S. A., has most kindly sent me a list of errata and misprints which he has found in the first volume of my Observatory Publications, while reading it with the MS. of his own general Catalogue of Double Stars. As it may be of service to some of the Fellows, I venture to ask for its insertion in the *Monthly Notices*.

Corrections.

Σ			
80	Colour	*For* ash	*Read* blue
87	Mag. of A	„ 8·5	„ 8·0.
112	Decl.	„ 45° 27′	„ 45° 41′.
300	Decl.	„ 38° 55′	„ 28° 55′.
376	Position	„ 351°·22	„ 251°·22.
444	Name	„ η	„ *n*.
548	Distance	„ 141″·97	„ 14″·197.
563	Decl.	„ 10° 50′	„ 40° 50′.
544	Epoch	„ 30·72	„ 31·72.
635	Decl.	„ 50° 51′	„ 54° 51′.
733	Decl.	„ 15° 57′	„ 15° 52′.
943	Position	„ 155°·90	„ 165°·90.
977	Decl.	„ 48° 45′	„ 48° 39′.
983	Colour	„ yelsh.	„ yel.
990	Decl.	„ −14° 16′	„ −14° 6′.
1012	„	„ 38° 20′	„ 28° 20′.
1058	„	„ 9° 37′	„ 9° 47′ (Pos. Med.)
1062	The Decl. measures and Magnitudes all belong to Σ 1065.		
1066	Epoch	„ 39·72	„ 29·72.

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1153	Decl.	*For*	12° 37′	*Read*	12° 20′.
1245	Mag of A	„	8·6	„	6·0.
1292	Decl.	„	0° 6′	„	−0° 6′.
1526	„	„	3° 22′	„	3° 30′.
1525	„	„	49° 9′	„	48° 9′.
1714	„	„	−24° 19′	„	24° 19′.
1727	Position	„	324°·97	„	334° 97′.
1806	Decl.	„	39° 7′	„	49° 7′.
1928	Position	„	227°·65′	„	277°·65.
1949	Decl.	„	13° 47′	„	13° 27′.
2008	„	„	2° 18′	„	−2° 18′.
2036	„	„	52° 49′	„	72° 49′.
2099	„	„	70° 23′	„	70° 35′ (Pos. Med.).
32[1]	„	„	47° 42′	„	47° 32′.
3110	„	„	−2° 45′·	„	−2° 25′.
2499	Position	„	329°·43	„	324°·93.
2589	Distance	„	5″·088	„	5″·008.
2601	Position	„	116°·05	„	166°·05.
60[2]	„	„	310°	„	210°.

Brook Street,
June 6, 1877.

Correction to Mr. Downing's Paper on the "Determination of the Semi-diameter of Venus at the Mean Distance of the Sun from the Earth," May No., pp. 398, 399.

The Author writes that he has discovered a slight inaccuracy in the computation of the Probable Errors on page 399. The corrections are:—

For $x = 0{\cdot}4439 \pm 0{\cdot}1036 \times e$
read $x = 0{\cdot}4439 \pm 0{\cdot}1369 \times e$;

For $y = -0{\cdot}02068 \pm 0{\cdot}00777 \times e$
read $y = -0{\cdot}02068 \pm 0{\cdot}01151 \times e$;

For semi-diam. = $8{\cdot}3693 \pm 0{\cdot}0664 \times e$
read semi-diam. = $8{\cdot}3693 \pm 0{\cdot}0955 \times e$.

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MONTHLY NOTICES

OF THE

ROYAL ASTRONOMICAL SOCIETY.

VOL. XXXVII. SUPPLEMENTARY NOTICE. No. 9.

Letter to the Hon. R. W. Thompson, Secretary of the Navy, announcing the Discovery of Satellites of Mars.

U.S. NAVAL OBSERVATORY, WASHINGTON,
August 21, 1877.

Sir,—The outer satellite of *Mars* was first observed by Professor Asaph Hall, U.S.N., on the night of August 11, 1877. Cloudy weather prevented the certain recognition of its true character at that time. On August 16 it was again observed, and its motion was established by observation extending through an interval of two hours, during which the planet moved over thirty seconds of arc.

The inner satellite was first observed on the night of August 17, and was also discovered by Professor Hall.

On Saturday, August 18, the discoveries were telegraphed to Alvan Clark & Sons, Cambridgeport, Mass., in order that if the weather should be cloudy at Washington, they might confirm the existence of the satellites with the 26-inch telescope of Mr. McCormick, which is in their hands.

This discovery was confirmed by Professor Pickering and his assistants, at Cambridge, Mass., and by the Messrs. Clark, at Cambridgeport.

On August 19, the discovery was communicated to the Smithsonian Institution, by which it was announced to the American and European observatories in the following despatch :—

Two satellites of Mars discovered by Hall, at Washington. First, elongation west, August 18, *eleven hours, Washington time. Distance, eighty seconds. Period, thirty hours. Distance of second, fifty seconds.*

It will be seen hereafter that the statement of fifty seconds as the distance of the inner one was erroneous.

The observations hitherto made are as follow :—

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The First Satellite.

	h	m				h	m				Observer.
			°					"			
1877, Aug. 11,	14	40,	p =	59·6	(2);	14	45,	s =	70·57	(2)	Hall.
16,	11	42,	.	.	.	.	.	.	s =	77·6	(1) Hall.
	13	7,	p =	71·9	(2);			.	s =	80·83	(4) Hall.
	13	36,	.	.	.	.	.	.	s =	80·4	(1) Hall.
17,	16	2,	p =	85·5	(2);	16	19,	s =	63·24	(3)	Hall.
18,	10	28,	p =	251·7	(3);	10	18,	s =	82·93	(8)	Newcomb.
	10	57,	p =	244·5	(1);	11	5,	s =	81·6	(1)	Harkness.
	11	50,	p =	246·6	(4);	11	57,	s =	81·77	(4)	Hall.
	14	32,	p =	232·1	(4);	14	39,	s =	61·04	(4)	Hall.
19,	11	42,	p =	283·2	(2);	11	49,	s =	46·20	(4)	Hall.
	15	43,	p =	255·4	(4);	15	52,	s =	81·37	(6)	Hall.
20,	10	28,	p =	61·1	(3);	10	33,	s =	76·07	(2)	Hall.
	11	57,	p =	52·1	(4);	12	7,	s =	59·93	(4)	Hall.

The Second Satellite.

1877, Aug. 17,	16	6,	p =	73·0	(2);	16	21,	s =	30·81	(4)	Hall.
18,	11	31,	p =	248·8	(2);	11	37,	s =	34·65	(4)	Hall.
19,	11	25,	p =	226·8	(2);	11	30,	s =	24·08	(2)	Hall.
20,	13	15,	p =	67·1	(1);	13	26,	s =	31·95	(3)	Hall.
	13	56,	.	.	.	.	.	.	s =	27·02	(4) Hall.
	14	22,	p =	70	(est.);	14	22,	s =	19·16	(3)	Hall.
	16	19,	p =	250	(est.);	16	19,	s =	15·15	(7)	Hall.
	16	35,	.	.	.	.	.	.	s =	16·70	(7) Hall.

From these observations Professor Newcomb has derived the following approximate circular elements of the orbits. The probable errors assigned are only very rough estimates.

The Outer Satellite.

Major semi-axis of apparent orbit seen at distance [9·5930] .	$82''{\cdot}5 \pm 0''{\cdot}5$
Minor semi-axis of apparent orbit seen at distance [9·5930] .	$27''{\cdot}7 \pm 2''$.
Major semi-axis of orbit seen at distance unity . . .	$32''{\cdot}3$
Position-angles of apsides of apparent orbit	$70°, 250° \pm 2°$
Passage through the west apsis (p = 250°), Aug. 19, $16^h{\cdot}6$, W.M.T.	
Period of revolution	$30^h\ 14^m \pm 2^m$
Hourly motion in Areocentric longitude	$11°{\cdot}907$
Inclination of true orbit to the ecliptic	$25°{\cdot}4 \pm 2$
Longitude of ascending node	$82°{\cdot}8 \pm 3$

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Position of pole of orbit in celestial sphere .	Long.	352·8
	Lat.	+ 64·6
	R.A.	316·1
	Decl.	+ 53·8
These elements give for the Mass of *Mars* .		$\frac{1}{3,090,000}$

The Inner Satellite.

Major semi-axis of apparent orbit at distance [9·5930] .	$33''{\cdot}0 \pm 1''$
Period of revolution	$7^h\ 38^m{\cdot}5 \pm 0^m{\cdot}5$
Hourly motion in Areocentric longitude	47°·11

Passage through the eastern apsis ($p = 70°$) Aug. 20, $13^h{\cdot}0$, W.M.T.

Very respectfully, your obedient servant,

JOHN RODGERS,

Rear Admiral and Superintendent.

The Hon. R. W. Thompson, Secretary of the Navy.

On the Solution of Kepler's Problem.

By J. W. L. Glaisher, M.A., F.R.S.

§ 1. Writing Kepler's equation in the form

$$x = a + e \sin x, \quad \ldots\ldots\ldots \quad (1)$$

the solution in powers of e is

$$x = a + e \sin a + \frac{e^2}{1.2}\frac{d}{da}(\sin^2 a) + \frac{e^3}{1.2.3}\frac{d^2}{da^2}(\sin^3 a) + \&c.,$$

and, on performing the differentiations, it will be found that

$$\begin{aligned} x = {} & a \\ & + e.\sin a \\ & + e^2.\sin a \cos a \\ & + e^3.\sin a \cos^2 a - \tfrac{1}{2}\sin^3 a \\ & + e^4.\sin a \cos^3 a - \tfrac{5}{3}\sin^3 a \cos a \\ & + e^5.\sin a \cos^4 a - \tfrac{11}{3}\sin^3 a \cos^2 a + \tfrac{13}{24}\sin^5 a \\ & + e^6.\sin a \cos^5 a - \tfrac{20}{3}\sin^3 a \cos^3 a + \tfrac{47}{15}\sin^5 a \cos a \\ & + e^7.\sin a \cos^6 a - \tfrac{65}{6}\sin^3 a \cos^4 a + \tfrac{1291}{120}\sin^5 a \cos^2 a - \tfrac{541}{720}\sin^7 a \\ & + e^8.\sin a \cos^7 a - \tfrac{49}{3}\sin^3 a \cos^5 a + \tfrac{427}{15}\sin^5 a \cos^3 a - \tfrac{1957}{315}\sin^7 a \cos a \\ & + \&c. \quad \ldots\ldots\ldots \quad (2) \end{aligned}$$

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Thus, as is well known, the expression

$$a+\frac{e\sin a}{1-e\cos a} \quad \ldots\ldots\ldots \quad (3)$$

differs from the root of the equation (1) only by quantities of the order e^3. It is also to be noticed that the second term of (3) represents the sum of the terms contained in the first column of (2), continued to infinity.

It is evident, therefore, that if the value of the series (2) had to be calculated up to the terms of the fourth or a higher order, it would be preferable to calculate the value of the second term in (3) rather than the values of the terms in the first column of (2), so that, in the calculation of the terms in the other columns, we may assume that the value of $\log(1-e\cos a)$ has been already obtained; and it is of some interest to examine whether these terms can be arranged in such a manner that the knowledge of the value of $\log(1-e\cos a)$ may be applied to reduce the number of logarithmic entries required for their calculation.

§ 2. It is clear that the terms in e^3 and e^4 in the second column of (2) can be represented by

$$\ldots -\frac{1}{2}\frac{e^3\sin^3 a}{(1-e\cos a)^{\frac{1}{2}9}},$$

so that

$$a+\frac{e\sin a}{1-e\cos a}-\frac{1}{2}\frac{e^3\sin^3 a}{(1-e\cos a)^{\frac{1}{2}9}} \quad \ldots\ldots \quad (4)$$

differs from the root of (1) only by quantities of the order e^5: in fact we find that

$$\begin{aligned} x = a &+\frac{e\sin a}{1-e\cos a}-\frac{1}{2}\frac{e^3\sin^3 a}{(1-e\cos a)^{\frac{1}{2}9}} \\ &+e^3.-\frac{1}{18}\sin^3 a\cos^2 a+\frac{13}{24}\sin^5 a \\ &+e^4.-\frac{20}{81}\sin^3 a\cos^2 a+\frac{47}{15}\sin^3 a\cos a \\ &+e^5.-\frac{325}{162}\sin^3 a\cos^4 a+\frac{1291}{120}\sin^5 a\cos^2 a-\frac{541}{720}\sin^7 a \\ &+e^6.-\frac{1039}{729}\sin^3 a\cos^6 a+\frac{427}{15}\sin^5 a\cos^4 a-\frac{1957}{315}\sin^7 a\cos a \\ &+\&c. \qquad\qquad \ldots\ldots \quad (5) \end{aligned}$$

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§ 3. The terms involving e^5 and e^6 in (5)

$$= e^5 . -\frac{1}{18} \sin^3 a \quad + \frac{43}{72} \sin^5 a$$

$$+ e^6 . -\frac{20}{81} \sin^3 a \cos a + \frac{1369}{405} \sin^5 a \cos a,$$

$$= e^5 . -\frac{1}{18} (1 + \frac{40}{9} e \cos a) \sin^3 a$$

$$+ e^5 . \frac{43}{72} (1 + \frac{10952}{1935} e \cos a) \sin^5 a;$$

so that these terms may be represented by

$$-\frac{1}{18} \frac{e^5 \sin^3 a}{(1 - e \cos a)^{\frac{40}{9}}} + \frac{43}{72} \frac{e^5 \sin^5 a}{(1 - e \cos a)^{\frac{10952}{1935}}} . \quad . \quad . \quad (6)$$

If the exponent $\frac{10952}{1935}$ be replaced by $\frac{17}{3}$, the first two terms of the expanded value are

$$\frac{43}{72} e^5 \sin^5 a (1 + \frac{10965}{1935} e \cos a),$$

which differs from the quantity to be represented by only

$$\frac{13}{3240} e^6 \sin^5 a \cos a = \frac{1}{249} e^6 \sin^5 a \cos a, \text{ nearly.}$$

Thus the expression

$$a + A,$$

where

$$A = \frac{e \sin a}{1 - e \cos a} - \frac{1}{2} \frac{e^3 \sin^3 a}{(1 - e \cos a)^{\frac{40}{9}}} - \frac{1}{18} \frac{e^5 \sin^5 a}{(1 - e \cos a)^{\frac{40}{9}}} + \frac{43}{72} \frac{e^5 \sin^5 a}{(1 - e \cos a)^{\frac{17}{3}}} \quad (7)$$

differs from the root of the equation (1) by

$$\frac{13}{3240} e^6 \sin^5 a \cos a + \text{terms of the seventh and higher orders,}$$

so that practically (7) gives the solution of Kepler's problem to the sixth order inclusive.

§ 4. Supposing the values of log e, log sin a, and log cos a to be given (in addition, of course, to the logarithms of the coefficients, which are assumed to be known), the calculation from (2) as it stands, up to the sixth order inclusive, would require twelve entries of the table of logarithms, while the calculation of log $(1 - e \cos a)$ requires two entries, and that of the terms in A four more, so that by the use of A six entries are saved. If log $(1 - e \cos a)$ be calculated and used in obtaining the first column of (2), the other terms in (2) require six entries, making nine in all, so that three are saved by the use of the last three terms of A. The calculation, of the expression (4), which

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gives the value of the root up to the fourth order inclusive, requires four entries, while the calculation from (2) requires six entries if the values of the separate terms in the first column are obtained, and five entries if they are replaced by

$$\frac{e \sin a}{1 - e \cos a}.$$

§ 5. On developing the expression A up to the seventh order, it is found to be

$$\begin{aligned}
&= e . \sin a \\
&+ e^2 . \sin a \cos a \\
&+ e^3 . \sin a \cos^2 a - \frac{1}{2} \sin^3 a \\
&+ e^4 . \sin a \cos^3 a - \frac{5}{3} \sin^3 a \cos a \\
&+ e^5 . \sin a \cos^4 a - \frac{65}{18} \sin^3 a \cos^2 a - \frac{1}{18} \sin^5 a + \frac{43}{72} \sin^5 a \\
&+ e^6 . \sin a \cos^5 a - \frac{520}{81} \sin^3 a \cos^3 a - \frac{20}{81} \sin^5 a \cos a + \frac{731}{216} \sin^5 a \cos a \\
&+ e^7 . \sin a \cos^6 a - \frac{2470}{243} \sin^3 a \cos^4 a - \frac{490}{729} \sin^5 a \cos^2 a + \frac{3655}{324} \sin^5 a \cos^2 a \\
&+ \&c.
\end{aligned}$$

$$\begin{aligned}
&= e . \sin a \\
&+ e^2 . \sin a \cos a \\
&+ e^3 . \sin a \cos^2 a - \frac{1}{2} \sin^3 a \\
&+ e^4 . \sin a \cos^3 a - \frac{5}{3} \sin^3 a \cos a \\
&+ e^5 . \sin a \cos^4 a - \frac{11}{3} \sin^3 a \cos^2 a + \frac{13}{24} \sin^5 a \\
&+ e^6 . \sin a \cos^5 a - \frac{20}{3} \sin^3 a \cos^3 a + \frac{2033}{648} \sin^5 a \cos a \\
&+ e^7 . \sin a \cos^6 a - \frac{7900}{729} \sin^3 a \cos^4 a + \frac{30935}{2916} \sin^5 a \cos^2 a \\
&+ \&c.
\end{aligned}$$

Subtracting this from (2), it appears that the correction to be *added* to A to give the true value of the root of the equation (1) is

$$\begin{aligned}
&e^6 . -\frac{13}{3240} \sin^5 a \cos a \\
&+ e^7 . \frac{5}{1458} \sin^3 a \cos^4 a + \frac{4363}{29160} \sin^5 a \cos^2 a - \frac{541}{720} \sin^7 a \\
&+ \&c.,
\end{aligned}$$

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which very nearly

$$= e^6 . -\frac{1}{249} \sin^5 a \cos a$$
$$+ e^7 . \quad \frac{1}{292} \sin^3 a \cos^4 a + \frac{3}{20} \sin^5 a \cos^2 a - \frac{3}{4} \sin^7 a$$
$$+ \&c., \qquad \ldots\ldots (8)$$

The smallness of the coefficients of the terms of the seventh order in (8) compared with those in (2) is worthy of remark: the sum of the first three coefficients in the e^7 line in (2) is equal to about 23 and in (8) to less than unity.

It is noticeable also how nearly the expression

$$-\frac{1}{2} \frac{e^3 \sin^3 a}{(1-e\cos a)^{\frac{1}{2}}}$$

represents the first *three* terms of the second column of (2), the coefficient of the third term differing from $\frac{11}{3}$ by only $\frac{1}{18}$. The quantity to be added to the expression in (4) to give the value of the root up to the fifth order inclusive is

$$e^5 . -\frac{1}{18} \sin^5 a + \frac{43}{72} \sin^5 a,$$

which

$$= e^5 . -\frac{1}{18} \sin^5 a + \frac{3}{5} \sin^5 a, \text{ nearly,}$$

since

$$\frac{3}{5} - \frac{43}{72} = \frac{1}{360}.$$

§6. The numbers within square brackets denoting the Briggian logarithms of the coefficients expressed in seconds, the value of A is

$$[5{\cdot}3144251] \frac{e \sin a}{1-e\cos a} - [5{\cdot}0133951] \frac{e^3 \sin^3 a}{(1-e\cos a)^{\frac{1}{2}}} - [4{\cdot}0591526] \frac{e^5 \sin^5 a}{(1-e\cos a)^{\frac{1}{2}}}$$
$$+ [5{\cdot}0905611] \frac{e^5 \sin^5 a}{(1-e\cos a)^{\frac{1}{2}}}.$$

As an example of the application of this formula, let $a = \frac{1}{4}$ and $e = 50°$, this being the example considered on pp. 376, 377 of this volume.

The work is then as follows, every figure that has to be written down being printed:—

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$\log e = 9{\cdot}3979400$ $\log \cos a = 9{\cdot}8080675$

$\log e^2 = 8{\cdot}1938200$ $\log \sin a = 9{\cdot}8842540$

$\log e^3 = 6{\cdot}9897000$ $\log \sin^3 a = 9{\cdot}6527620$

$\log \sin^5 a = 9{\cdot}4212700$

$\log e$	9·3979400
$\log \cos a$	9·8080675
	9·2060075
$e \cos a$	0·1606969
$1 - e \cos a$	0·8393031
$\log (1 - e \cos a)$	9·9239189
Ar. Co.	0·0760811 $= \log P$, say,
	0·008453456 $= \log P^{\frac{1}{9}}$
	0·25360368 $= \log P^{\frac{3}{9}} = \log P^{\frac{1}{3}}$
	0·33813824 $= \log P^{\frac{4}{9}}$
	0·42267280 $= \log P^{\frac{5}{9}}$
	0·43112626 $= \log P^{\frac{6}{9}} = \log P^{\frac{2}{3}}$

(+)	(−)	(−)	(+)
5·3144251	5·0133951	4·05915	5·09056
9·3979400	8·1938200	6·98970	6·98970
9·8842540	9·6527620	9·65276	9·42127
0·0760811	0·2536037	0·33814	0·43113
4·6727002	3·1135808	1·03975	1·93266
"	"	"	"
47065·23	1298·91	10·96	85·64
85·64	10·96		
47150·87	1309·87		
1309·87			

$45841{\cdot}00 = 12^\circ\ 44'\ 1''{\cdot}00$;

thus $A = 12^\circ\ 44'\ 1''{\cdot}00$, and

$$x = a + A, = 62^\circ\ 44'\ 1''{\cdot}00, \quad \ldots\ldots \quad (9)$$

the true value being (see p. 377) $62^\circ\ 43'\ 56''{\cdot}00$.

The value of the expression in (4), that is of a + the first two terms of A, $= 62^\circ\ 42'\ 46''$, and the correction for terms of the fifth order, viz.:

$$e^5 . -\frac{1}{18} \sin^3 a + \frac{3}{5} \sin^5 a$$

$= -5''{\cdot}03 + 31''{\cdot}88$, giving $x = 62^\circ\ 43'\ 13''$.

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§7. The correction to be applied to (7) in order to include approximately the terms of the seventh order, viz.:

$$e^7 . \frac{3}{20} \sin^5 a - \frac{9}{10} . \sin^7 a$$

$= 0''{\cdot}50 - 1''{\cdot}75 = -1''{\cdot}25$. As the error of (9) is about $5''$, it will be seen that, the seventh order correction just obtained being very small, there is very little advantage in including these terms. In general, the classification of the terms according to orders of e supposes that e is very small; so small, in fact, that a term involving e^{n+1} may be regarded as distinctly smaller than one involving e^n: but if e be as large as $\frac{1}{4}$, the terms of the orders near to e^8 do not differ much from one another in magnitude, in consequence of the increased values of the coefficients, which somewhat counteract the effect of the additional factor e. This is readily seen by considering the terms in e^8. By expanding the terms in A, it will be found that the terms in e^8, omitting the first, are

$$= -14{\cdot}90809 \sin^3 a \cos^5 a - 1{\cdot}44389 \sin^5 a \cos^3 a + 28{\cdot}82887 \sin^5 a \cos^3 a$$
$$= -16{\cdot}35198 \sin^3 a \cos^5 a + 27{\cdot}38498 \sin^5 a \cos^3 a \quad \ldots\ldots\ldots (10)$$

(in which the coefficients are expressed as decimals so that their magnitudes may be more evident): the terms in e^8 in (2), omitting the first, are

$$= -16{\cdot}33333 \sin^3 a \cos^5 a + 28{\cdot}46667 \sin^5 a \cos^3 a - 6{\cdot}21270 \sin^7 a \cos a$$
$$\ldots\ldots\ldots (11)$$

and the difference

$$= e^8 . 0{\cdot}01865 \sin^3 a \cos^5 a + 1{\cdot}08169 \sin^5 a \cos^3 a - 6{\cdot}21270 \sin^7 a \cos a :$$

in the case of $e = \frac{1}{4}$, this difference $= 0''{\cdot}00 + 0''{\cdot}24 - 1''{\cdot}95$ $= -1''{\cdot}71$.

The close agreement between the coefficients of $\sin^3 a \cos^5 a$ and $\sin^5 a \cos^3 a$ in (10) and (11) is remarkable; and it will be noted that the coefficient of the new term, viz. the term in $\sin^7 a \cos a$, is, as in the case of the terms of the seventh order, much the largest.

It thus appears that if e be so large that, in order to obtain the value of x to the nearest tenth or hundredth of a second, terms of a higher order than the sixth have to be included, in general no great additional accuracy will be obtained by applying to A the corrections for the terms of the seventh and eighth orders, while of course if the terms in e^7 may be neglected, the corrections are insensible. Whenever, therefore, the series in (2) affords a suitable solution of the problem, the expression $a + A$ gives the solution up to the seventh order, and in general but little additional accuracy is gained by applying the corrections

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for the seventh and higher orders. The advantage of using the formula $a+A$ would be greatest if e were very small, so that the order of e governed the magnitude of each term, and if the value of x were required with great exactness; as, for example, if the accuracy required were such that ten-figure logarithms had to be employed in the calculation of the first term of A, but that terms above e^7 were insensible.

The following are the values of the terms in (2), for this case of $e=\frac{1}{4}$, $a=50°$, up to the sixth order inclusive :—

$$\begin{aligned} x &= 50° \\ &\quad + 39502''{\cdot}00 \\ &\quad + 6347''{\cdot}85 \\ &\quad + 1020''{\cdot}08 - 724''{\cdot}40 \\ &\quad + 163''{\cdot}92 - 388''{\cdot}03 \\ &\quad + 26''{\cdot}34 - 137''{\cdot}18 + 28''{\cdot}78 \\ &\quad + 4''{\cdot}23 - 40''{\cdot}08 + 26''{\cdot}76 \\ &= 50° + 45830''{\cdot}27 = 62°\ 43'\ 50''{\cdot}27; \end{aligned}$$

the terms in e^7

$$\begin{aligned} &= +0''{\cdot}68 - 10''{\cdot}47 + 14''{\cdot}76 - 1''{\cdot}46 \\ &= 3''{\cdot}51; \end{aligned}$$

and the terms in e^8

$$\begin{aligned} &= 0''{\cdot}11 - 2''{\cdot}54 + 6''{\cdot}28 - 1''{\cdot}95 \\ &= 1''{\cdot}90; \end{aligned}$$

so that, when the seventh order terms are included, the value is $62°\ 43'\ 53''{\cdot}78$; and when the terms of the eighth order are also included, $62°\ 43'\ 55''{\cdot}68$.

§ 8. As another example, let $e=\frac{1}{10}$, $a=50°$, and the terms of A

$$= 16886''{\cdot}23 - 57''{\cdot}85 - 0''{\cdot}07 + 0''{\cdot}47,$$

so that $a+A=54°\ 40'\ 28''{\cdot}78$, which will be found to satisfy the equation to within the hundredth of a second.

§ 9. The exponents in the denominators of the terms in A are $\frac{30}{9}$, $\frac{40}{9}$, $\frac{51}{9}$; if the last exponent be taken to be $\frac{50}{9}$, the sixth order error

$$= +\frac{101}{1620}e^6 \sin^5 a \cos a, \quad = +\frac{1}{16}e^6 \sin^5 a \cos a, \text{ nearly,}$$

and is thus much larger than when the exponent is $\frac{51}{9}$, the error in this case (*see* § 3) being

$$= -\frac{1}{249}e^6 \sin^5 a \cos a, \text{ nearly.}$$

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§ 10. If the terms in (2) be treated in columns as in §§ 2 and 3, each column being kept distinct, it will be found that up to the sixth order inclusive,

$$x = a + \frac{e \sin a}{1 - e \cos a} - \frac{1}{2} \frac{e^2 \sin^2 a}{(1 - e \cos a)^3} - \frac{1}{18} \frac{e^3 \sin^3 a \cos^2 a}{(1 - e \cos a)^5} + \frac{13}{24} \frac{e^5 \sin^5 a}{(1 - e \cos a)^7},$$

so that

$$x = a + \mathrm{B},$$

where

$$\mathrm{B} = \frac{e \sin a}{1 - e \cos a} - \frac{1}{2} \frac{e^2 \sin^2 a}{(1 - e \cos a)^3} - \frac{1}{18} \frac{e^3 \sin^3 a \cos^2 a}{(1 - e \cos a)^5} + \frac{13}{24} \frac{e^5 \sin^5 a}{(1 - e \cos a)^7},$$

the correction to be added to B being

$$e^6 . \frac{9}{480} \sin^5 a \cos a$$

$$+ e^7 . \frac{5}{1458} \sin^3 a \cos^4 a + \frac{947}{3840} \sin^5 a \cos^2 a - \frac{541}{720} \sin^7 a$$

$$+ \&c.,$$

which, very nearly,

$$= e^6 . \frac{1}{53} \sin^5 a \cos a$$

$$+ e^7 . \frac{1}{292} \sin^3 a \cos^4 a + \frac{1}{4} \sin^5 a - \sin^7 a$$

$$+ \&c.$$

It is clear that the expression B is not so convenient for calculation as A; and also the residual sixth order term is larger for B than for A.

§ 11. In t. v. (1859) of the *Annales de l'Observatoire de Paris*, pp. 349, 350,* M. Serret gives an account of a method, indicated by M. Leverrier on p. 192 of t. i., of solving Kepler's problem by means of a series of a different form to (2). The method is as follows:—

Let x_0 be an approximate value of x, and put

$$v = a - x_0 + e \sin x_0;$$

then

$$x - e \sin x = x_0 - e \sin x_0 + v.$$

This is the equation to be solved, and we can calculate x by

* "Note sur l'équation dont dépend l'anomalie excentrique, et sur les séries qui se présentent dans la théorie du mouvement elliptique des corps célestes."

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developing it in ascending powers of v by Maclaurin's theorem; we have

$$(1-e\cos x)\frac{dx}{dv}=1,$$

$$(1-e\cos x)\frac{d^2x}{dv^2}+e\sin x\left(\frac{dx}{dv}\right)^2=0,$$

$$(1-e\cos x)\frac{d^3x}{dv^3}+3e\sin x\frac{dx}{dv}\frac{d^2x}{dv^2}+e\cos x\left(\frac{dx}{dv}\right)^3=0,$$

&c. &c.

When $v=0$, $x=x_0$, and

$$\frac{dx}{dv}=\frac{1}{1-e\cos x_0},\quad \frac{d^2x}{dv^2}=-\frac{e\sin x_0}{(1-e\cos x_0)^3},$$

$$\frac{d^3x}{dv^3}=\frac{3e^2\sin^2 x_0}{(1-e\cos x_0)^5}-\frac{e\cos x_0}{(1-e\cos x_0)^4},$$

whence

$$x=x_0+\frac{1}{1-e\cos x_0}v-\frac{1}{2}\frac{e\sin x_0}{(1-e\cos x_0)^3}v^2$$

$$+\left\{\frac{1}{2}\frac{e^2\sin^2 x_0}{(1-e\cos x_0)^5}-\frac{1}{6}\frac{e\cos x_0}{(1-e\cos x_0)^4}\right\}v^3+\&c.,\quad\ldots\ldots\quad(12)$$

In the case of an orbit in which e is very small, put $x_0=a$, then $v=e\sin a$ and, neglecting terms of the fourth order,

$$x=a+\frac{e\sin a}{1-e\cos a}-\frac{1}{2}\left(\frac{e\sin a}{1-e\cos a}\right)^3.\quad\ldots\ldots\quad(13)$$

M. Serret remarks that this formula is very convenient for calculation, and that the last term can be immediately derived from the previous term.

§ 12. It will be found that the coefficient of v^4 in (12) is

$$-\frac{5}{8}\frac{e^3\sin^3 x_0}{(1-e\cos x_0)^7}+\frac{5}{12}\frac{e^2\sin x_0\cos x_0}{(1-e\cos x_0)^6}+\frac{e\sin x_0}{(1-e\cos x_0)^5};$$

and therefore, putting $x_0=a$, the formula, whose first three terms are given by M. Serret's equation (13), is

$$x=a+\frac{e\sin a}{1-e\cos a}-\frac{1}{2}\frac{e^2\sin^2 a}{(1-e\cos a)^3}$$

$$+\frac{1}{2}\frac{e^3\sin^3 a}{(1-e\cos a)^5}-\frac{1}{6}\frac{e^4\sin^3 a\cos a}{(1-e\cos a)^6},$$

$$-\frac{5}{8}\frac{e^7\sin^7 a}{(1-e\cos a)^7}+\frac{5}{12}\frac{e^6\sin^5 a\cos a}{(1-e\cos a)^6}+\frac{1}{24}\frac{e^5\sin^5 a}{(1-e\cos a)^5}$$

$$+\&c.;\quad\ldots\ldots\quad(14$$

the second line being derived from the terms in v^3, and the third from those in v^5.

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In the case of $e = \frac{1}{4}$, $a = 50°$, this gives

$$x = 50° + 47065''{\cdot}23 - 1225''{\cdot}24$$
$$+ \quad 63''{\cdot}79 - \quad 78''{\cdot}20$$
$$- \quad 4''{\cdot}15 + \quad 9''{\cdot}16 + 5''{\cdot}32$$
$$+ \&c.$$

		°	′	″
The first line	=	52	43	59·99
the second line	= −			14·41
the third line	= +			10·33
		52	43	55·91

The close approximation afforded by the first line (the error is only 3″·99) is very remarkable, but it is of course accidental; the term of the fourth order = 78″·20, and those of the fifth order amount to 69″·11.

§ 13. The formula (13), which is true to the third order, only differs from (4), which is true to the fourth order, in the exponent of the denominator, which is $\frac{10}{3}$ instead of 3. If $e = \frac{1}{10}$, $a = 50°$, the last term of (13) = 56″·59; and the value of x from (13) is 54° 40′ 29″·64, and from (4) is 54° 40′ 28″·38, the true value as found in § 8 being 54° 40′ 28″·78.

As another example, let $e = \frac{1}{7}$, a being, as before, 50°, then (14) gives

$$x = 50° + 24854''{\cdot}92 - 180''{\cdot}45$$
$$+ \quad 2''{\cdot}62 - \quad 6''{\cdot}08$$
$$- \quad 0''{\cdot}05 + \quad 0''{\cdot}22 + 0''{\cdot}22$$
$$+ \&c.;$$

the first line = 56° 51′ 14″·47, the second − 3″·46, and the third 0″·39, leading to $x = 56°\ 51'\ 11''{\cdot}40$; and the true value obtained by substituting this in (1) is 56° 51′ 11″·39.

The value of $a + A$ is

$$50° + 24854''{\cdot}92 - 186''{\cdot}34 - 0''{\cdot}47 + 3''{\cdot}34,$$

which = 56° 51′ 11″·45.

The value obtained from (4) is 56° 51′ 8″·58.

§ 14. It will be noticed that in both these examples the formula (13) affords a very close approximation to the true value; this is due to the fact that the terms in the second line of (14) nearly counteract one another for the values of e and a that have been taken; for, these terms

$$= \frac{1}{2} \frac{e^4 \sin^3 a}{(1 - e \cos a)^4} \{e \sin^2 a - \frac{1}{3} \cos a\},$$

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and the term in brackets is small for the assumed values of e and a. As an example in which this is not the case, let $e = \frac{1}{4}$, $a = 130°$, then (14) gives

$$\begin{aligned} &130° + 34032''{\cdot}99 - 463''{\cdot}25 \\ &\quad + \quad 12''{\cdot}61 + \quad 21''{\cdot}38 \\ &\quad - \quad 0''{\cdot}43 - \quad 1''{\cdot}46 + 1''{\cdot}05. \end{aligned}$$

The first line $= 139°\ 19'\ 29''{\cdot}74$, the second $33''{\cdot}99$, and the third $-0''{\cdot}84$, leading to $x = 139°\ 20'\ 2''{\cdot}89$.

The value of $a + \mathrm{A}$

$$\begin{aligned} &= 130° + 34032''{\cdot}99 - 440''{\cdot}81 - 2''{\cdot}59 + 13''{\cdot}64 \\ &= 139°\ 20'\ 3''{\cdot}23. \end{aligned}$$

The value of x given by (4) is $139°\ 19'\ 52''{\cdot}18$, which only differs from the true result (viz. $139°\ 20'\ 2''{\cdot}93$) by about $11''$. It is evident that the effect of the denominators in (7) and (14) is to increase the magnitudes of the terms if a be in the first or fourth quadrants, and diminish them if a be in the second or third quadrants.

The expression in (4) is only very slightly more complicated than (13), and as it represents the root to one order higher, it is in general to be preferred.

§ 15. The series in (14) is clearly the expansion of x in powers of $\frac{e}{1 - e\cos a}$, and it may therefore be obtained directly in the following manner:—

Let

$$\epsilon = \frac{e}{1 - e\cos a},$$

then

$$e = \frac{\epsilon}{1 + \epsilon\cos a};$$

the equation is

$$x = a + \frac{\epsilon}{1 + \epsilon\cos a}\sin x,$$

viz.

$$x = a + \epsilon(\sin x - x\cos a + a\cos a),$$

and therefore, by Lagrange's theorem,

$$\begin{aligned} x = a + \epsilon\sin a + \frac{\epsilon^2}{1.2}\frac{d}{dx}(\sin x - x\cos a + a\cos a)^2 \\ + \frac{\epsilon^3}{1.2.3}\frac{d^2}{dx^2}(\sin x - x\cos a + a\cos a)^3 + \&c., \quad . \quad . \quad . \quad (15) \end{aligned}$$

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x being put equal to a after the differentiations have been performed; thus

$$\begin{aligned} x = \quad & a \\ & + e \,.\, \sin a \\ & + e^2 \,.\, -\frac{1}{2} \sin^2 a \\ & + e^4 \,.\, -\frac{1}{6} \sin^2 a \cos a \\ & + \&c. \end{aligned}$$

It is evident that there will be no terms in the expansion involving powers of $a \cos a$, for

$$\sin x - x \cos a + a \cos a = \sin a, \text{ when } x = a,$$

and its differential coefficient $= \cos x - \cos a$. When $x = a$ this vanishes, and the terms are in consequence greatly simplified: in fact, the development of (15) may be very rapidly effected.

§ 16. A similar method affords the expansion of x in powers of $\frac{e}{1 + e \cos a}$; for, let

$$\eta = \frac{e}{1 + e \cos a},$$

then

$$x = a + \frac{\eta}{1 - \eta \cos a} \sin x,$$

viz.

$$x = a + \eta (\sin x + x \cos a - a \cos a),$$

and therefore

$$\begin{aligned} x = a + \eta \sin a + & \frac{\eta^2}{1.2} \frac{d}{dx} (\sin x + x \cos a - a \cos a)^2 \\ & + \frac{\eta^3}{1.2.3} \frac{d^2}{dx^2} (\sin x + x \cos a - a \cos a)^3 + \&c., \end{aligned}$$

x being put equal to a.

We thus find

$$\begin{aligned} x = \quad & a \\ & + \eta \,.\, \sin a \\ & + \eta^2 \,.\, 2 \sin a \cos a \\ & + \eta^3 \,.\, 4 \sin a \cos^2 a - \frac{1}{2} \sin^3 a \\ & + \eta^4 \,.\, 8 \sin a \cos^3 a - \frac{19}{6} \sin^3 a \cos a \\ & + \eta^5 \,.\, 16 \sin a \cos^4 a - \frac{40}{3} \sin^3 a \cos^2 a + \frac{13}{24} \sin^5 a \\ & + \&c. \end{aligned}$$

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The first column evidently

$$= a + \frac{\eta \sin a}{1 - 2\eta \cos a}, = a + \frac{e \sin a}{1 - e \cos a}.$$

§ 17. I here add another solution of Kepler's problem in series, the denominators of the terms being powers of $1 - e \cos a$.

If

$$x = a + efx$$

then, by Lagrange's theorem,

$$Fx = Fa + efaF'a + \frac{e^2}{1.2}\frac{d}{da} f^2aF'a + \frac{e^3}{1.2.3}\frac{d^2}{da^2} f^3aF'a + \&c.$$

Now let

$$Fx = \frac{1}{1 - ef'x} = \frac{dx}{da},$$

therefore

$$\frac{dx}{da} = \frac{1}{1 - ef'a} + \frac{e^2faf''a}{(1 - ef'a)^2} + \frac{e^3}{1.2}\frac{d}{da}\frac{f^2af''a}{(1 - ef'a)^2} + \frac{e^4}{1.2.3}\frac{d^2}{da^2}\frac{f^3af''a}{(1 - ef'a)^2} + \&c.$$

$$= 1 + \frac{ef'a}{1 - ef'a} + \frac{e^2faf''a}{(1 - ef'a)^2} + \frac{e^3}{1.2}\frac{d}{da}\frac{f^2af''a}{(1 - ef'a)^2} + \&c.;$$

whence, integrating,

$$x = a + \frac{efa}{1 - ef'a} + \frac{e^2}{1.2}\frac{f^2af''a}{(1 - ef'a)^2} + \frac{e^4}{1.2.3}\frac{d}{da}\frac{f^3af''a}{(1 - ef'a)^2} + \&c.$$

In the case of Kepler's problem

$$fa = \sin a, \quad f'a = \cos a, \quad f''a = -\sin a;$$

and therefore

$$x = a + \frac{e \sin a}{1 - e \cos a} - \frac{e^2}{1.2}\frac{\sin^2 a}{(1 - e \cos a)^2} - \frac{e^4}{1.2.3}\frac{d}{da}\frac{\sin^4 a}{(1 - e \cos a)^2}$$

$$- \frac{e^5}{1.2.3.4}\frac{d^2}{da^2}\frac{\sin^5 a}{(1 - e \cos a)^2} - \&c.$$

$$= a + \frac{e \sin a}{1 - e \cos a}$$

$$- \frac{e^2}{2}\frac{\sin^2 a}{(1 - e \cos a)^2}$$

$$- \frac{e^4}{3}\left\{2\frac{\sin^2 a \cos a}{(1 - e \cos a)^2} - \frac{e \sin^2 a}{(1 - e \cos a)^3}\right\},$$

$$- \frac{e^5}{24}\left\{20\frac{\sin^2 a}{(1 - e \cos a)^2} - 25\frac{\sin^2 a}{(1 - e \cos a)^3} - 22\frac{e \sin^2 a \cos a}{(1 - e \cos a)^3} + 6\frac{e^2 \sin^2 a}{(1 - e \cos a)^4}\right\},$$

$$- \&c.$$

1877, *August* 4.

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Note on the Arc of Light seen round Venus in Transit.

By R. A. Proctor, Esq.

My attention has been directed to remarks made on this subject after the reading of a paper by Mr. Brett relating to *Venus*. The paper itself I need not refer to. But the remarks upon it have raised hopes in some minds that it may be possible to increase the intrinsic brightness of light from a disk or other visible surface (as distinguished from bodies like the stars, which are reduced appreciably to points by distance). For it was assumed, in the first place, that the arc of light seen round *Venus* in transit (whether she is partly or wholly immersed) is really brighter than the Sun's disk; and it was maintained in the second place, that this superior brightness could be accounted for either by the effects of a refractive atmosphere, or by specular reflexion at the surface of *Venus*. If this were so, it would be easy to produce the same effect artificially. The faint light of planetary disks, of nebulæ, of comets, etc., might be strengthened, and at the same time rendered more suitable for direct spectroscopic observation, by interposing something of the nature of a large thermometer bulb—any opaque globe in fact, within a transparent envelope of suitable refractive qualities. This would be an important gain. Unfortunately there is no reason for hoping that it can ever be attained. The apparently superior brightness of the arc of light seen round *Venus*, or round a thermometer bulb held before a gas flame, or the like, is demonstrably due to two causes, neither implying any real accession of brightness, viz.—first, the effect of contrast against the dark disk within the refracting envelope, secondly and chiefly to the fact that the comparison is made between the light of some less brilliant part of the disk or other surface, and light from the whole disk or surface brought into view by refraction. It will be found on careful trial, if the effect of contrast be removed or greatly diminished (which can readily be done), that under no circumstances does the arc of so-called condensed light exceed or even equal in brilliancy the brightest part of the luminous surface beyond. And this, which is found experimentally to be the case, can readily be shown to be necessarily so. In an article entitled 'Notes on Brightness' in a weekly journal of science, I showed four years ago that by no optical contrivances can apparent brightness be increased, though quantity of light can of course be greatly increased. *Venus* in transit does not differ in this respect from a portion of an enormous optical instrument directed towards the Sun, and the same general reasoning applies to her. It is, however, easily seen, if we take her case specially, that the law holds good. Thus, consider a small strip of the Sun's disk lying on a diameter through *Venus*,—take two points along this strip separated by a distance δr so small that the variation of the amount of refrac-

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tion by which rays from points along the arc between these points reach the eye of a terrestrial observer may be considered uniform. Suppose that by the effects of refraction the distance δr, which seen directly from the Earth has that apparent length, is reduced in length, when forming a part of the arc of light round *Venus*, to $\frac{1}{k}\delta r$, k being greater than unity. Then it is obvious that each pencil of rays from points along the luminous strip δr has its divergency in the plane through the strip, *Venus's* centre, and the Earth's, increased, as $k : 1$, in passing along its course (whatever this may be) through the atmosphere of *Venus*. This follows from the uniform variation of the amount of bending for points differently placed along the strip δr. Hence the eye receives fewer rays from each point of the strip δr in the ratio of $1 : k$. Wherefore, neglecting the absorptive effect of *Venus's* atmosphere,

app. brightness of strip δr seen round edge of δ : its app. brightness seen directly

$$:: \frac{\text{light recd. round } \delta \text{ from each pt. of strip}}{\text{apparent area of strip as seen round } \delta} : \frac{\text{light recd. from each pt. of strip directly}}{\text{apparent area of strip seen directly}}$$

$$:: \frac{1}{k} + \frac{1}{k}\delta r : \frac{1}{\delta r}$$

$$:: 1 : 1,$$

or the brightness is unchanged.

I may take this opportunity of noting that, in a paper on the Nebulæ recently read before the Royal Society, it is asserted that an irresolvable stellar nebula would diminish in apparent brightness (so far as the stellar part of its light is concerned) with increase of distance. No reasoning is given in support of this assertion; and I can see no reason for withdrawing the reasoning by which, in a paper on the Resolvability of Nebulæ regarded as a Test of Distance, I show (incidentally) that a nebula so long as it remained irresolvable would be of constant intrinsic brightness whatever its distance* (always supposing there is no extinction of light in traversing space).

Margate, June 2, 1877.

Absorption of the Light of Venus by Dark Violet Glass Plates.

By Prof. Zenger.

In October 1876 I observed Venus, to detect spots on it, and so look out for the alleged phosphorescent light of the dark part of the disk. I could observe *Venus* early in the morning during nearly the whole of October; it was then very brilliant, casting a shadow, and by its light making it possible to read the maps on the illuminated wall of the observatory. I could even see

* I have since heard that Prof. Stokes, after the paper had been read before the Royal Society, indicated the error into which its writer had fallen in this respect.

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the planet with the naked eye at $21^h\ 30^m$ and $21^h\ 40^m$ October 11 and 12, the atmosphere being very calm and pure. On September 30, $20^h\ 12^m$, and the following day, October 1, $17^h\ 15^m$, the disk was admirably defined in the telescope, and there was observed a very brilliant patch near the southern horn some two seconds or less from the terminator in the dark parts of the disk, and this was still visible for two days, when the terminator had passed it, shining like a brilliant star in the surrounding part of the illuminated disk.

This observation induced me to try a new method of photometric measurement by dark violet glass plates, putting one or two between the eye-piece and the eye, and determining the distance at which the light of a lamp vanished by one and then by two plates. I found the proportional intensity to be nearly 1 : 5·6 for one to two. Viewing the planet, it was very striking to observe the great diminution of light on the illuminated disk, as the borders vanished entirely by putting two plates before the eye. I lost sight of nearly one-third of the illuminated part, and the middle of it was with only one plate reduced to nearly one-third of its brilliancy. I therefore concluded that, putting the intensity of the most brilliant part of the planet = 1, and dividing the nearly one-half illuminated part in three parts, the intensities of each were nearly as

$$1 : 1 \div 3 : 1 + 5{\cdot}6, \text{ that is as } 5{\cdot}6 : 1{\cdot}9 : 1.$$

It is obvious that, using a bi-prism with parallel planes, as for solar eye-pieces, and making one of the prisms of dark violet glass, the other being colourless crown glass, there will be a possibility of applying a scale of intensity by the difference of depth of the violet glass, and of measuring with more accuracy the intensity of such brilliant objects as *Venus*, *Jupiter*, the Moon, &c. It seemed to me to be of interest to communicate these observations, as they confirm the results by a quite different method published in one of the last Numbers of the *Monthly Notices*, and giving a new instance of very highly reflecting points on the surface of *Venus* (perhaps snow-covered high peaks) being visible, like on the Moon, before the solar light reaches the lower parts of the surrounding surface. I could never perceive any trace of the so-termed specular reflection, though I think it would have been perceived if there had been in the middle of the planetary disk such a higher intensity of reflected light in a round or elliptical shape.

The diminution of light in the same longitude from the terminator seemed equal all over the disk of the planet, and not changed under different latitudes, as it should be in case of specular reflection.

P.S.—Though I could detect a faint grayish light, sometimes ruddy near the terminator, during the time from September 30 to October 14, the atmosphere being uncommonly transparent, yet I could never see the whole of the dark part of *Venus*,

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though the planet afforded, from 16^h to 18^h in the morning of three days of October, a most splendid view. On the contrary, it seemed with daybreak to be more easy to see the faint illumination near the terminator, even to two-thirds of the whole breadth of the dark part of *Venus*.

Prague, February 17, 1877.

Measures of α Centauri, 1870 to 1877.

By H. C. Russell, Esq., Director of the Sydney Observatory.

As the double star α *Centauri* did not arrive at periastron in 1875 as predicted, perhaps the following measures of this interesting double, taken during the ordinary course of my observations on southern double stars, during the past seven years, may not be without interest. It is evident from these observations that a^2 will not make its nearest approach to a^1 until about the end of this year. Its predicted arrival at that point was therefore nearly three years in error. It is my intention to observe it closely during the next few months; and I hope to obtain such a series of measures as may serve to determine its periastron with accuracy. Some correction may be necessary to my position-angles, on account of *personal bias*, for I find that I do not measure the angle the same when the telescope is east as I do when it is west of the pier (see observations of July 20 and July 24, 1877), but I have not time to investigate the amount before this mail closes.

The observations from 1870 to 1874 were made with a $7\frac{1}{4}$-in. refractor by Merz, of 10 ft. 4 in. focus, and very fine defining power. The remainder have been made with an $11\frac{1}{2}$-in. refractor by Schroeder, a very fine instrument. The method of observing is to place the position-wire bisecting both stars, and then make the distance wires bisect them. After reading, the position-wire is turned right away, and brought back again, and the distance wires crossed; each observation, therefore, which follows is an independent determination of the distance and position-angle. The only exception is the series September 27, 1870, when the position-circle was not moved after it was set the first time.

All the observations, except those in 1870, were taken when the star was near the meridian.

Results of Measures of Double Star α Centauri, at the Sydney Observatory.

Date. 1870	Position-Angle. °	′	Distance. ″	Remarks.
Sept. 27	21	58	10·0	Definition good; stars have sharp round disks; telescope $7\frac{1}{4}$ inches; P. 230; aperture 3 inches.
	21	58	11·0	
	21	58	10·7	
	21	58	10·7	
	21	58	9·6	
Means	21	58	10·40	

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Date.	Position-Angle.	Distance.	Remarks.
1870	° ′	″	
Sept. 28	23 24	10·3	Light clouds about; stars very unsteady; telescope 7¼; power 150.
	24 17	10·3	
	21 44	10·3	
	21 55	11·0	
Means	22 50	10·47	
Oct. 3	22 5	10·1	Fine clear night; "moonlight"; telescope 7¼; power 150.
	22 30	10·4	
	22 11	10·3	
	22 16	10·3	
	22 43	10·2	
Means	22 21	10·26	
Oct. 5	21 40	10·8	Strong wind; much vibration; telescope 7¼; power 150.
	21 58	11·0	
	22 28	10·3	
	21 44	10·3	
	22 36	11·1	
Means	22 5	10·70	
1871			
June 3	23 20	10·60	Power 230; telescope 7¼.
	21 42	10·31	
	23 13	10·23	
	23 11	10·27	
	22 13	10·05	
	23 49	10·46	
	23 8	10·05	
	22 52	10·03	
	22 33	10·34	
	23 3	10·16	
Means	22 44	10·25	
July 13	22 57	10·05	Stars dancing a good deal; telescope 7¼.
	23 15	10·16	
	22 47	9·86	
	23 23	9·82	
	23 5	10·21	
Means	23 5	10·2	

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Date.	Position-Angle.	Distance.	Remarks.
1872	° ′	″	
June 7	26 13	9·95	Very thick fog; at times scarcely visible; telescope 7¼; power 150.
	25 43	9·82	
	26 3	9·69	
	25 40	9·84	
	25 58	9·73	
	25 48	9·75	
Means	25 54	9·80	
July 5	25 0	9·62	Stopped by clouds; measures good; telescope 7¼; power 150.
	24 46	9·75	
	24 30	9·62	
Means	24 45	9·66	
1873			
May 2	28 52	9·45	Stars dancing; aperture of 3 inches; power 333; telescope 7¼.
	28 45	9·45	
	27 56	9·66	
	28 17	9·66	
	27 59	9·36	
	28 37	9·40	
Means	28 4	9·50	
1874			
June 13	30 16	7·80	Good definition; measures good; power 140; telescope 7¼.
	30 26	7·67	
	29 33	7·76	
	29 21	7·63	
	30 19	7·69	
	30 13	7·84	
	30 6	7·50	
	30 3	7·56	
	30 21	7·76	
	29 29	7·89	
Means	29 59	7·71	

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Date.	Position-Angle.	Distance.	Remarks.
1874	° ′	″	
June 29	30 19	8·19	Good definition; full moon; measures of distance not good; power 140; telescope 7¼.
	30 12	8·17	
	30 0	7·93	
	30 8	8·21	
	30 9	8·08	
	29 53	8·34	
	30 5	8·45	
	29 44	8·10	
	29 50	8·47	
	29 58	8·32	
Means	30 2	8·23	
1875	...	...	Observer away in Europe.
1876			
May 23	45 5	4·39	Stars tremulous, and very watery; power 180; aperture 6 inches; first measures with 11½ inches.
	46 30	4·52	
	46 0	4·62	
	46 15	4·55	
	45 40	4·52	
	46 25	4·57	
	46 35	4·50	
	45 40	4·52	
	46 10	4·48	
	46 30	4·27	
Means	46 5	4·49	
June 8	47 47	4·2	Moderately steady; one disk seems about ⅛ more in diameter than the other; telescope 11½; power 544.
	48 0	3·81	
	47 52	4·30	
	47 10	4·23	
	48 28	4·70	
	47 42	4·41	
	48 15	4·38	
	48 10	4·22	
	48 8	4·20	
	47 10	4·34	
Means	47 52	4·20	

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Date.	Position-Angle.	Distance.	Remarks.
1877	° ′	″	
July 5	72 56	2·713	Aperture 8 inches; power 450; stars dancing; telescope 11½.
	72 56	2·803	
	72 46	2·445	
	73 2	2·766	
	72 46	2·731	
	72 59	2·481	
	72 21	2·642	
	73 24	2·392	
	72 56	2·427	
	72 36	2·570	
Means	72 52	2·597	
July 7	72 57 mean		6 measures; power 450.
	72 31 „		8 „ „ 800.
July 20	78 57	1·818	Telescope on west side of pier; star 2 hours before meridian; definition not good; aperture 5 inches; power 500; telescope 11½.
	79 40	2·179	
	80 25	2·161	
	80 40	1·999	
	79 33	2·179	
	79 15	1·999	
	78 40	2·089	
	78 7	2·071	
	79 28	2·071	
	79 45	2·143	
Means	79 27	2·071	
July 24	75 40	2·269	Aperture 7 inches; power used 800; telescope on east side; star 2 hours past meridian; telescope 11½ inches.
	76 30	2·071	
	75 55	2·125	
	75 35	2·071	
	76 12	2·287	
	75 45	2·105	
Means	75 56	2·155	

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Date.	Position-Angle.	Distance.	Remarks.
1877	° ′	″	
July 25	76 50	2·089	Aperture 5 inches; power 800; telescope on east side of pier; definition not very good; stars dancing. Great care taken with these observations, but the position-angle is very difficult, owing to the motion or unsteadiness of the stars. Clouds were passing, and at times obscured both stars, but oftener only α^2, which I estimate as fully one-third, or nearly one-half, less than α^1. The varying thickness of the clouds enabled me to estimate the relative brilliance.
	75 0	2·197	
	77 35	2·089	
	77 3	2·197	
	76 28	2·161	
	76 5	1·927	
	76 20	1·999	
	75 20	2·053	
	77 40	2·215	
	77 30	2·143	
	76 30	2·179	
	75 15	2·017	
	76 10	2·251	
	75 30	2·071	
Means	76 22	2·113	

Sydney Observatory, July 27, 1877.

Observations of the Lunar Eclipse, 1877, August 23. By the Rev. Samuel J. Johnson.

The total eclipse of the Moon was seen here as well under an English as under an oriental sky, not a cloud intervening throughout. I employed a power of 70 on 2¼ in.

9.10 Penumbra dimmed the N.E. quadrant of the Moon considerably. At 8.45 I had not been able to satisfy myself about the presence of it. Precise time of commencement difficult to determine. At 9.15 the shadow was evidently impinging on the neighbourhood where *Olbers* is marked.

9.18½ Immersion of *Grimaldi*.

9.22½ Shadow reached *Aristarchus*.

9.32¾ *Copernicus* reached. For 3 min. or 4 min. an orange tint has been visible at the edge of the Moon. *Aristarchus* comes out most distinctly in the shadow.

9.39¾ *Plato* reached.

9.40¾ *Archimedes* reached.

9.49¼ *Tycho* reached. *Aristoteles* same time. Copper tint readily seen with unassisted vision.

9.51 Immersion of *Tycho*.

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9.55 The three ψ's in *Aquarius* coming into view to the naked eye.

10.5 So-called seas in the eclipsed Moon beginning to be very prominent. *Mare Serenitatis* standing out nearly black, darker than any other part of the lunar surface.

10.13¼ Immersion of *Mare Crisium*. *Mare Crisium*, *Mare Fœcunditatis*, and the region south of them of a greenish hue. The rest of the eclipsed disk of a coppery tint.

10.18·2 Emersion of a star about mag. 7½ from a point in a line with south extremity of *Mare Crisium*. Angle about 100°.

10.20 Total obscurity.

10.24·9 Star mag. 7 occulted, angle about 80°. It exhibited the illusion of projection more plainly than I have ever noticed, appearing to lie within the Moon's limb 3" or 4".

11.8·0 Emersion of small star mag. 8. Angle about 110°.

11.15 The central regions darkest, being about the time of mid-eclipse; the illumination round the borders tolerably uniform now.

11.45 Crescent of yellow light on Moon's eastern limb. *Mare Crisium*, *Fœcunditatis*, *Nectaris*, *Tranquilitatis*, *Serenitatis* in a smoky gloom; above and below this region the prevailing tint orange.

12.4¼ First streak of sunlight. This outbreak was so clearly marked that it might have been noticed by the naked eye within 3" or 4" of the instant the telescope showed it.

12.7¼ Emersion of *Grimaldi*.

12.14¼ Emersion of *Aristarchus*.

12.27½ Emersion of *Copernicus*.

12.30½ Emersion of *Plato*.

12.31¼ Emersion of *Tycho*.

12.35 Emersion of *Archimedes*. Milky Way beginning to fade out of sight, now half the Moon is uncovered.
A slight brownish tinge mingling with the grey could be detected until 12.55.

13.0¾ *Mare Crisium* began to emerge.

13.5 Emersion of the *Mare Crisium*.
A few degrees north of this, the shadow left the Moon about 13.8½.

(Angles of Stars occulted reckoned same way as in *N.A.*)

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There was an absence of that flickering light on the reddened disk of the Moon which I noticed last February, and which was probably due simply to the undulations of our own atmosphere, but which Professor Dorna of Turin ascribed to the action of a lunar aurora, saying that the refraction of the Sun's rays within the cone of the Earth's shadow was not an adequate explanation. (See *L'Opinione Nazionale*, March 3).

I had requested another observer, only 35 sec. long. further east than here, to note the time of the first outbreak of sunlight on the Moon, as a simultaneous observation, and the result gave a difference of longitude almost precisely accurate.

Upton Helions Rectory, Crediton.

On the Spectrum of Comet b 1877 (*Winnecke's*) *and of the Eclipsed Moon, observed at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The position of Comet *b* 1877 was so inconvenient for observation with the Great Equatoreal when armed with the long Single Prism Spectroscope, that it was found practically impossible to obtain any measures of the bands in the Spectrum, though on May 15 the Dun Echt Observations (*Monthly Notices*, 1877, June) were so far confirmed that the spectrum of the coma was found to consist of three bands in the neighbourhood of the three principal carbon bands, wave-lengths 4834, 5203, and 5607, whilst that from the nucleus appeared to be continuous. For more exact determination of position, a small Half Prism Spectroscope, giving a dispersion of 20° from A to H with a magnifying power of 9 on the viewing telescope, was used, and this, being only 16 inches in length and consequently much shorter than the other spectroscope, allowed sufficient room for the observer within the polar axis. With this greater dispersion the spectrum of the nucleus no longer appeared continuous, and the wave-length of the brightest band was determined (by six indirect comparisons with the carbon band 5203) to be 5178, with a probable error of 5 tenth-metres. The measures were made by turning the half-prism by means of a screw, so as to bring the cometary band to coincide with the bright reference line formed by the image of the comet on the slit, and then comparing the latter with the band in the carbon spectrum.

During the Eclipse of the Moon on 1877 August 23, the spectrum was observed with the Single Prism Spectroscope during totality and also during the partial phase, when the portion of the Moon's disk still in the umbra was repeatedly compared with the part which had emerged. During totality (about 11^h G.M.T.) a strong absorption band was seen in the yellow, and the red and blue ends of the spectrum were

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completely cut off, whilst the orange was greatly reduced in intensity. The yellow and green were comparatively bright, and in fact appeared at a first glance to constitute the whole visible spectrum. The wave-length of the more refrangible edge of the strong absorption band was found, from a mean of 9 measures, to be 5624 ± 5, and at about 11^h it extended to wave-length 5900, i.e. as far as D. As the end of the total phase approached ($12^h\ 4^m$), the band became narrower, its breadth being only twice the interval of the D lines at $11^h\ 45^m$, and at $12^h\ 20^m$, during the partial phase, it was reduced to a mere line on the eclipsed portion. This band is coincident with the strong band δ of the atmospheric spectrum as given by Brewster and Gladstone, which is peculiarly characteristic of the spectrum of light which has passed through a thick stratum of air. The red end of the spectrum was cut off by a dark band commencing about halfway from D to C, in which a black line was suspected. About the middle of totality a dark band, commencing at $5080 \pm$ (near band ι of the Brewster-Gladstone spectrum) cut off all the rest of the spectrum, but later on at $11^h\ 30^m$ the spectrum was visible as far as about 4930 (the position of band κ in the atmospheric spectrum). After the end of totality the red and blue ends of the spectrum from the eclipsed portion became visible beyond these limits. The appearance of the spectrum of the part clear of the umbra, though still in the penumbra, was totally different, even when reduced to the same degree of faintness by closing the slit. In this case the spectrum faded out as a whole from beyond D to near G in the violet.

The part of the Moon examined when the band δ was darkest was the region of *Mare Nectaris* and *Mare Fœcunditatis*, and the band could be seen only on the darkest part of the Moon when *Kepler* was just emerging from the umbra, growing rapidly fainter as the spectroscope was moved away towards the bright part.

The light by which the eclipsed Moon is visible would thus appear to have passed through a great thickness of the earth's atmosphere, giving rise to the peculiar copper colour.

The observations were made by Mr. Christie and Mr. Maunder.

Royal Observatory, Greenwich,
1877, *August* 28.

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INDEX.

PAGE

Abbe, on O. M. Mitchel's observations at Cincinnati 121
Abney, Capt. W. de W., effect of a star's rotation on its spectrum 278
Airy, Sir G. B., note on his numerical lunar theory 245
——— Oral address on suspected intra-mercurial planet, and on approaching opposition of *Mars* 246
See Greenwich Observatory.
Altazimuth stand, on a method of obtaining equatoreal motion by a simple addition to, Lord Lindsay 1
——— description of an improved, for reflecting telescopes, with a new form of binocular eye-piece, Mr. Thornthwaite..... 3
André, M. Ch., on his diffraction experiments, and observations of transits, Mr. Perry..... 56, 59
Angot, A., étude sur les images photographiques obtenues au foyer des lunettes astronomiques..... 387
——— sur l'application de la photographie à l'observation du passage de *Vénus* 392
Arcimis, Señor, observations of the Lunar Eclipse of 1876, September 3, made at Cadiz 12
——— on the visibility of the unilluminated portion of the disk of *Venus* 259
——— phenomena of *Jupiter's* satellites, observed at Cadiz..... *ib.*
——— observations of occultations of stars by the Moon, made at Cadiz in the year 1876..... 261
——— Lunar Eclipse of the 27th February 1877, observed at Cadiz 400
Ariadne, on the opposition of the minor planet, as a means of determining the solar parallax, Mr. Gill..... 327
Astronomy, report on the progress of, in the year 1876-77:—
The numerical lunar theory..... 180
Reduction of the observations of the transit of *Venus*, December 8, 1874 181
M. Le Verrier's planetary researches 184
The Nautical Almanac for 1880 185
Solar physics..... *ib.*
Discovery of minor planets 188
Discovery of a new comet 189
D'Arrest's periodical comet ..... *ib.*
Santiago de Chile observations 190
Physical observations of *Saturn* 191
Observations of *Jupiter's* satellites at Adelaide..... 192
Drawings of *Jupiter* ..... *ib.*
The supposed discovery of the object perturbing the motion of *Procyon* 193
Photographs of spectra of stars 195
New double stars ..... *ib.*
Micrometric measures of double stars..... 196
Doberck's new elements of the orbit ω Leonis 197
Dun Echt Observatory publications 199
The new star in *Cygnus* 200
Suspected change in nebula Messier, No. 17 (the Horseshoe nebula) 202
Montigny's researches on scintillation 203
Progress of meteoric astronomy in the year 1876..... 205
——— correction..... 362

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PAGE
Backhouse, J. W., on the nomenclature of meteor radiant points 281
Ball, Prof. R. S., observations of minor planets with the transit-circle at Dublin (Dunsink) 14
——— note on a transformation of Lagrange's equations of motion in generalised co-ordinates, which is convenient in physical astronomy 265
Boë, M. de, on a method of destroying the vibrations on a mercurial reflector 409
Brett, J., the specular reflexion hypothesis, and its bearing on the transit of *Venus* 126
Brightness, apparent, as an indication of distance in stellar masses, Mr. Stone 232
Burnham, S. W., note on the double star H_d I. 62 280

Campbell, Capt. W. M., on a peculiarity of personal equation 283
Capron, J. R., report of Examination of Sun's disk at Guildford, March 21, 22, and 23, for suspected planet *Vulcan* 348
Cayley, Prof. A., on spheroidal trigonometry 92
——— addition to Prof. Ball's paper on Lagrange's equations of motion 269
Christie, W. H. M., on the effect of wear in the micrometer-screws of the Greenwich transit-circle 18
——— note on the gradation of light on the disk of *Venus* 90
Comets:
1877. I. Borelly 189, 360
,, II. Winnecke 359, 360
D'Arrest's (search for) 360
b and *c*, 1877, Spectra of, Lord Lindsay 430
b, 1877, spectrum of 469
Copeland, Dr. R., on two "flats" in the Moon's limb, observed March 23, 1877 432

Darwin, G. H., on an oversight in the Mécanique Céleste, and on the internal densities of the planets 77
Denning, W. F., observations of shooting stars, April to December 1876 105
——— radiant points of shooting stars, from Capt. Tupman's unreduced observations, 1869–71 349
Diffraction experiments, on those of M. C. André with reference to astronomical instruments, and the general theory of this diffraction, Mr. Perry 56
Downing, A. W., a determination of the semi-diameter of *Venus* at the mean distance of the Sun from the Earth 398
——— correction to foregoing paper 442
Dreyer, J. L. E., note on some of M. Stephan's new nebulæ 427
Dun Echt Observatory Publications 232

Eclipses:
lunar of 1876, September 3, S. Arcimis 12
1877, February 27, Mr. Penrose 262
,, ,, ,, Mr. Perry 263
,, ,, ,, S. Arcimis 400
,, August 23, Mr. Johnson 467
,, ,, ,, spectrum observations 469
Eclipse, solar of 1876, September 17, Mr. Tebbutt 11
Ellery, R. L. J., observations on *α Centauri* 435
Equinoctial time, table for facilitating the determination of, Admiral Shadwell 401
Erck, W., an improved mode of viewing the Sun 128
Errata 282
Eye-piece, a new solar, Prof. Zenger 439

Digitized by Google

PAGE

Fellows deceased, list of 143
Sheepshanks, Miss Ann (Honorary) ... *ib.*
Becker, Rear-Admiral A. B. ... 145
Cheyne, C. H. H. ... 147
Corbet, Lieut. C., R.N. ... 148
Edwards, the Rev. J. ... 150
Middlemist, the Rev. R. ... 151
Otter, Rear-Admiral H. C. ... 152
Rosaz, the Chevalier F. de ... 153
Strange, Lieut.-Col. A. ... 154
Yeates, A. ... 159
Fellows elected ... 1, 41, 93, 129, 231, 283, 363, 427
Finlay, W. H., a method of deducing the formula for correcting the computed time of an observed occultation for errors in the elements adopted ... 16

Gasparis, M. A. de., on Kepler's problem ... 263
Gill, D., on the proposed expedition to observe the approaching opposition of *Mars* ... 310
——— on the opposition of the minor planet *Ariadne* as a means of determining the solar parallax ... 327
——— on the opposition of the minor planet *Melpomene*, as a means of determining the solar parallax ... 412
Glaisher, J. W. L., on an elliptic function solution of Kepler's problem 366
———, on the solution of Kepler's problem ... 445
Gledhill, J. W., and Wilson, J. M., a preliminary list of binary and other interesting double stars ... 64
Green, N. E., note on the coming opposition of *Mars* ... 424
Greenwich Observatory. Spectroscopic results for the motions of stars, and of *Venus* in the line of sight, and for the Sun and *Jupiter* 22
——————— spectroscopic results for the rotation of *Jupiter*, and of the Sun ... 43
——————— observations of occultations of stars by the Moon, and of phenomena of *Jupiter's* satellites, made in the year 1876 ... 116
——————— stars to be compared in R.A. with *Mars* 1877, for determination of the parallax of *Mars* ... 117
——————— on spectrum of Comet *b* 1877 (Winnecke's) and of the eclipsed Moon, August 23 ... 469

Harkness, Prof., W., theory of the horizontal photoheliograph, including its application to the determination of the solar parallax by means of transits of *Venus*. (Abstract.) ... 93
Hind, J. R., on the orbit of *α Centauri* ... 96
——— on two ancient occultations of planets by the Moon, observed by the Chinese ... 243
Holden, Prof. E. S., The nebula in *Orion*, request to Astronomers ... 231
Howlett, Rev. F., his Sun-spot drawings ... 364

Johnson memorial prize ... 362
Johnson, Rev. S. J., visible transits of *Mercury* to the year 2000 ... 425
——— lunar eclipse of 1877, August 23 ... 467
Juno, note on the results of heliometer observations of, to determine its diurnal parallax, Lord Lindsay and Mr. Gill ... 308
Jupiter, ephemeris for physical observations of, Mr. Marth ... 241
———, spectroscopic observations for rotation of ... 22, 43
Jupiter's satellites, phenomena of, observed at the Greenwich Observatory 116
——————— at Cadiz, Señor Arcimis ... 259
——————— at the Observatory, Adelaide, and notes on the physical appearance of the planet, Mr. Todd ... 284
——————— at the Radcliffe Observatory, Oxford 340

Digitized by Google

PAGE
Kepler's problem, M. de Gasparis 263
——— two mechanical solutions of, Prof. Pritchard 354
——— Gylden's elliptic function solution of, Mr. Glaisher 366
——— on the solution of, by the same 445
Knott, G., micrometrical measures of double stars. (Abstract.)..... 95
——— on the variable star U *Geminorum* 279

Lagrange's equation of motion, note on a transformation of, in generalised co-ordinates, convenient in physical astronomy, Prof. Ball 265
——— addition to foregoing paper, Prof. Cayley 269
Langley, Prof., measurement of the direct effect of Sun-spots on terrestrial climates 5
Lassell, W., on the space-penetrating power of Mr. Lassell's 2-foot and 4-foot reflectors 124
Leverrier, M., letter on suspected ultra-mercurial planet 229
Lindsay, Lord, note on a method of obtaining equatoreal motion by means of a simple addition to an altazimuth stand 1
——— the Dun Echt Observatory publications 232
——— on the spectra of comets *b* and *c*, 1877 430
——— corrections to Struve's double stars contained in the Dun Echt Observations, vol. i. 441
——— and Mr. Gill, note on the results of heliometer observations of the planet *Juno*, to determine its diurnal parallax 308
Lunar observations, an attempt to simplify the method of making corrections for the spheroidal figure of the Earth in, and particularly with reference to its effect on the lunar distance, Mr. Penrose... 39
Lunar theory, the numerical, Sir G. B. Airy 245
——— perturbations by *Jupiter*, Mr. Neison 248, 358
——— Prof. Newcomb..... 428

Main, the Rev. R, observations of occultations of stars by the Moon 1875, 1876, 1877 (with the deduced equations between the errors of the lunar elements), and of the phenomena of *Jupiter's* satellites, made at the Radcliffe Observatory, Oxford 340
Mars, discovery of satellites of 443
—— stars to be compared in R.A. with *Mars* 1877, for determination of the parallax of *Mars* 117
—— ephemeris for physical observations of *Mars*, 1877, Mr. Marth..... 301
—— the approaching opposition of, M. Terby 232
——— Mr. Proctor 423
——— Mr. Green 424
—— the proposed expedition to observe the approaching opposition of *Mars*, Mr. Gill 310
Marth, A., on the Orbit of *a Centauri* 61
——— ephemeris for determining the positions of the satellites of *Uranus*, 1877 98
——— ephemeris for physical observations of *Jupiter*, 1877 241
——— *Mars*, 1877..... 301
Mécanique Celeste, on an oversight in, and on internal densities of the planets, Mr. Darwin 77
Meigs, General M. C., on a method of making a pendulum swing in an approximately cycloidal arc 410
Melpomene, on the opposition of, as a means of determining the solar parallax, Mr. Gill..... 412
Mercurial reflector, method of destroying the vibrations of, M. de Boë... 409
Mercury, visible transits of, to the year 2000, Mr. Johnson 425
Meteors and shooting-stars, observations of, April to December, 1876, Mr. Denning 105
——— radiant points of shooting stars, from Capt. Tupman's unreduced observations, 1869–71 349

Digitized by Google

PAGE

Meteor, the great, of 1877, March 17, Capt. Tupman 353
——— radiant points, on nomenclature of Mr. Blackhouse 281
Meteors, supposed fall of, at Supino, P. Secchi 364
Meucci, Prof., extract of a letter on Arabian celestial globe 426
Micrometer-screws of Greenwich transit-circle, on the effect of wear in, Mr. Christie 18
Minor Planets, observations of, at Dublin (Dunsink), Prof. Ball 14
——— see *Ariadne, Juno, Melpomene.*
Mitchel, O. M., his observations at Cincinnati, Mr. Abbe 121
Moon's limb, two flats observed March 23, 1877, Dr. Copeland 432
Nebulæ (new) discovered and observed at the observatory of Marseilles, 1876 and 1877, M. Stephan 334
——— note on same, Mr. Dreyer 427

Neison, E., on the position of the point of maximum brightness on *Venus* 89
——— on the lunar perturbations arising from the planet *Jupiter* 248
Newcomb, Prof. S. J., on observations of contacts of the limb of *Venus* or *Mercury* with that of the Sun 237
——— note on the new inequalities in the Moon's longitude pointed out by Mr. Neison 428

Observatories—accounts of proceedings of:—
Royal, Greenwich 161
Radcliffe, Oxford 163
Oxford University 164
Cambridge 166
Dunsink, Dublin 167
Royal, Edinburgh 168
Glasgow 169
Kew 170
Liverpool, Bidston, Birkenhead ..... *ib.*
Temple, Rugby 171
Stonyhurst 172
Mr. Barclay's ..... *ib.*
Mr. Bishop's ..... *ib.*
Col. Cooper's 173
Mr. Crossley's ..... *ib.*
Mr. Huggins's 174
Lord Lindsay's ..... *ib.*
Earl of Rosse's 175
Col. Tomline's ..... *ib.*
Royal, Cape of Good Hope 176
Melbourne 177
Occultation, a method of deducing the formulæ for correcting the computed time of an observed, for errors in the elements adopted, Mr. Finlay 16
Occultations of stars by the Moon:—
Greenwich observations of, in the year 1876 116
1875, 1876, 1877, at the Radcliffe Observatory, Oxford, Mr. Main ... 340
at Cadiz, in 1876, Senor Arcimis 261
Windsor, N.S.W., 1876, Mr. Tebbutt 434
Regulus, 26 February 1877, Mr. Penrose 262
Occultations of planets by the Moon, two ancient Chinese observations of, Mr. Hind 243
Orion, the nebula in: request to astronomers, Prof. Holden 231

Parallax, see *Mars, Ariadne, Juno, Melpomene.*
Pendulum, method for a cycloidal, General Meigs 410

Digitized by Google

PAGE

Penrose, F. C., an endeavour to simplify the method of making the correction for the spheroidal figure of the Earth in lunar observations, and particularly with reference to its effect upon the "lunar distance" 39
——————— the occultation of *Regulus*, February 26, 1877 262
——————— total eclipse of the Moon, February 27, 1877 ..... *ib.*
——————— description of an improved diagram for the graphical solution of spherical triangles, applicable to the questions arising out of the spheroidal figure of the Earth, and further illustrated by reference to the prediction of occultations 403
Perry, the Rev. S. J., on some diffraction experiments of M. Ch. André, with reference to astronomical instruments, and the general theory of this diffraction 56
——————— on the phenomena exhibited by a planet in its transit across the solar disk, from observations made by M. Ch. André 59
——————— eclipse of the Moon, February 27, 1877 263
——————— the planet *Vulcan* 347
——————— some experiments bearing on the transit of *Venus* 386
Personal equation, on a peculiarity of, Capt. Campbell 283
Photoheliograph, horizontal, on the theory of, including its application to the determination of the solar parallax by means of the transits of *Venus*, Prof. Harkness. (Abstract.)..... 93
Planets, on internal densities of, and on an oversight in the Mécanique Céleste, Mr. Darwin 77
Planet, the suspected intra-mercurial:—
——— Letter from M. Leverrier 229
——— Sir G. B. Airy 246
——— search for, March 21, 22, 23, Mr. Perry 347
——————— Mr. Capron..... 348
Plumbline, note on deviation of, M. Struve 362
Plummer, J., on the conjunction of *Venus* and λ *Geminorum*..... 102
——————— on the collective light and distribution of the fixed stars... 436
Pritchard, the Rev. Prof. C., two mechanical solutions of Kepler's problem 354
——————— the comets of 1877 360
Proctor, R. A., the approaching opposition of *Mars*..... 423
——————— note on the distribution of fixed stars 424
——————— note on the line of light seen round *Venus* in transit..... 459

Robinson, the Rev. Dr., on the relative space-penetrating power of reflectors and refractors 282
Royston-Pigott, Dr., on photographing solar transits by means of the starlit transit eye-piece, and other methods 271
Russell, H.C., measures of α Centauri, 1870 to 1877 462

Seabroke, G. M., and Wilson, J. M., second catalogue of measures of double stars at the Temple Observatory. (Abstract.)..... 399
Secchi, Padre, note on the alleged fall of an aërolite at Supino, Italy..... 365
Shadwell, Adm. Sir C., a table for facilitating the determination of mean equinoctial time to the end of the present century..... 401
Society:—
Report of Council to fifty-seventh annual meeting 129
List of papers read from February 1876 to February 1877 221
List of donors to the library 225
Election of officers and Council 228
Space-penetrating power, on the relative, of refractors and reflectors, M. Struve..... 89
——————— Mr. Lassell ... 124
——————— Dr. Robinson .. 282
Spectroscopic results for the motions of stars and of *Venus* in the line of sight, and for the rotation of the Sun and *Jupiter*, made at the Royal Observatory, Greenwich..... 22, 43

Digitized by Google

PAGE
Spectrum, effect of star's rotation on its, Capt. Abney 278
Spectra of comets *b* and *c*, 1877, Lord Lindsay 430
Specular reflexion hypothesis and its bearing on the transit of *Venus*, Mr. Brett 126
Spherical triangles, diagram for graphical solution of, with reference to spheroidal figure of the Earth and to occultations, Mr. Penrose 403
Spheroidal trigonometry, Prof. Cayley 92
Starlit transit eye-piece, on photographing solar transits by means of; and other methods, Dr. Royston-Pigott 271
Stars, on the distribution of, Mr. Proctor 424
—— collective light and distribution of, Mr. Plummer 436
Stars, double or multiple:—
On the orbit of *α Centauri*, Mr. Marth 61
———— Mr. Hind 96
Observations of, Mr. Ellery 435
———— Mr. Russell 462
Preliminary list of binary and other interesting double stars, Messrs. Wilson and Gledhill 64
Micrometrical measures of, Mr. Knott. (Abstract.) 95
Second catalogue of micrometrical measures of, at Temple Observatory, by Messrs. Wilson and Seabroke 399
ℍ I. 62, Mr. Burnham 280
Stars, variable, U *Geminorum*, Mr. Knott 279
—— *γ Argûs*, on magnitude of, Mr. Tebbutt 280
Stephan, M., new nebulæ discovered and observed at the Observatory of Marseilles, 1876 and 1877 334
Stone, E. J., on some phenomena of the internal contacts common to the transits of *Venus*, observed in 1769 and 1874, and some remarks thereon 45
———— on apparent brightness as an indication of distance in stellar masses 232
Struve, O., on the relative space-penetrating power of the Pulkova 15-inch refractor and Mr. Lassell's 4-foot reflector 89
———— note on a deviation of the plumbline 362
———— his double stars in Dun Echt Observatory publications 232
———— correction to same 441
Sun, an improved method of viewing the, Mr. Erck 128
Sun-spots, measurement of the direct effects of, on terrestrial climates, Prof. Langley 5
———— note on same paper, Mr. Williams 41
———— drawings, the Rev. F. Howlett's 364

Tebbutt, observations of the solar eclipse of 1876, September 17 11
———— on the magnitude of *γ Argûs* 280
———— occultations observed at Windsor, N.S. Wales, in the year 1876 434
Tennant, Col. J., on the error of the tabular place of *Venus* on December 8, 1874 45
Terby, M., the approaching opposition of *Mars*, request to astronomers 232
Thornthwaite, description of an improved altazimuth stand for reflecting telescopes, with a new form of binocular eye-piece 3
Todd, observations of the phenomena of *Jupiter's* satellites at the Observatory, Adelaide, and notes on the physical appearance of the planet 284
Transits, on photographing solar, by means of starlit transit-eye-piece, Dr. Royston-Pigott 271
———— of a planet across the solar disk, on the phenomena exhibited by, from observations by M. C. André, Mr. Perry 59
———— on observations of contacts of the limb of *Mercury* or *Venus* with that of the Sun, Prof. Newcomb 237

Digitized by Google

PAGE

Transit of *Venus*, 1874, December 8:
Error of planet's tabular place, Col. Tennant 45
Corrections to *N.A.* places of the Moon for longitude observations in connexion with, Capt. Tupman 249
Transits of *Venus*, 1769 and 1874, on some phenomena of internal contacts common to, and remarks thereon, Mr. Stone 45
Tupman, Capt. G. L., corrections to the *N.A.* places of the Moon for longitude observations in connection with the transit of *Venus* 249
——— his observations of shooting stars 1869-71, Mr. Denning 349
——— the Great Meteor of 1877, March 17 353

Uranus, satellites of, 1877, ephemeris for determining the positions of the, Mr. Marth 98

Venus, spectroscopic results for motion of 23
——— on the position of the point of maximum brightness of, Mr. Neison 89
——— on gradation of light on the disk of, Mr. Christie 90
——— the specular reflexion hypothesis, and its bearing on the transit of, Mr. Brett 126
——— on visibility of unilluminated portion of disk of, Señor Arcimis ... 259
——— experiments bearing on transit of, Mr. Perry 386
——— Mr. Angot 387, 392
——— determination of semi-diameter of, at mean distance of Sun from the Earth, Mr. Downing 398
——— correction to same paper 442
——— on line of light round her in transit, Mr. Proctor 459
——— absorption of light of, by dark violet glasses, Prof. Zenger 460
——— and λ *Geminorum*, on conjunction of, Mr. Plummer 102
Vulcan, see Planet, suspected intra-Mercurial 347

Williams, W. M., note on Prof. Langley's paper on the direct effect of Sun-spots on terrestrial climates 41
Wilson, J. M., and Gledhill, J. W., a preliminary list of binary and other interesting double stars 64
Wilson, J. M., and Seabroke, G. M., second catalogue of micrometrical measurements of double stars, made at the Temple Observatory. (Abstract.) 399
Winnecke, Prof., comet 1877, II. discovered by 359

Zenger, Prof., a new solar eye-piece 439
——— absorption of the light of *Venus* by dark violet glass plates ... 460

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LIST OF PRESENTS

RECEIVED DURING THE SESSION OF 1876-77,

AND OF

BOOKS PURCHASED WITH THE TURNOR FUND

DURING THE SAME PERIOD,

FORMING

APPENDIX XXVIII.

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